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**OBJECTIVE FUNCTIONAL SHOULDER TESTING IN INDIVIDUALS
WITH ATRAUMATIC ANTERIOR SHOULDER INSTABILITY**

BY

JUDITH CAROL CHEPEHA



A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of
the requirements for the degree of **MASTER OF SCIENCE**.

DEPARTMENT OF PHYSICAL THERAPY

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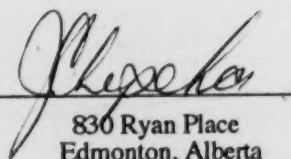
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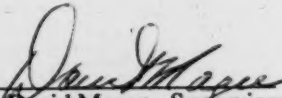
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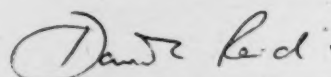
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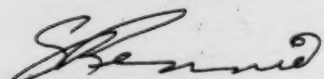
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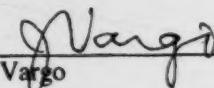
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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **OBJECTIVE FUNCTIONAL SHOULDER TESTING IN INDIVIDUALS WITH ATRAUMATIC ANTERIOR SHOULDER INSTABILITY** submitted by **JUDITH CAROL CHEPEHA** in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE**.


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Dated: June 30 1997

DEDICATION

I would like to dedicate this work to my parents in thanks for all they have given and continue to give to me today. My achievements thus far, are as a result of being taught to always work hard, to accept only my very best, and to grow, learn and experience life to its fullest. The love, support and friendship that they have always provided me has assisted me immensely in life. Thank you, you truly inspire me.

ABSTRACT

The purpose of this study was to utilize three objective functional shoulder tests: the Shoulder Rotation Test (SRT), the Light Board Test (LBT) and the Overhead Throw Test (OTT), and compare the results generated from these tests on experimental subjects with atraumatic anterior shoulder instability and control subjects with normal shoulders. The results attained from these function tests were also compared to two subjective rating scores, one representing function (Simple Shoulder Test) and one representing pain and sense of instability (Visual Analogue Scales).

Forty subjects participated in the study, twenty in the experimental group and twenty in the control group. Descriptive statistics and t-test analyses were calculated for all of the tests that were performed, to determine if a difference occurred between the two study groups. Correlation tests were used to calculate the correlations between the function tests and the subjective rating scores.

The SRT and the OTT demonstrated statistically significant differences between the two groups of subjects studied. The two subjective rating scores produced similar statistically significant differences, however only a small number of correlations were found to be significant between the variables examined.

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I would like to thank my advisor, Dr. David Magee, for providing me, in himself, an example that I could look up to. The completion of this project would not have been possible without his guidance and encouragement.

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CHAPTER 1 THE PROBLEM

A. Statement of the Problem

Atraumatic Anterior Shoulder Instability (AASI) is a clinical condition seen commonly in sports and occupations that involve overhead positions and movements. As a result of this overhead activity, plus the inherent anatomical considerations of the glenohumeral (GH) joint itself, the shoulder is particularly vulnerable to injury (Abrams, 1991; Andrew et al, 1991; Andrews and Wilk, 1994).

Disruption of the integrity at the GH joint can result in a disabling injury associated with labral tears and/or ligament damage, rotator cuff tears, fractures and neural involvement (Warren, 1983; Matsen and Zuckerman, 1991). These are often associated with pain, instability and overall decreased function from apprehension during certain shoulder movements. If the individual's livelihood in sport or work is dependent upon his/her shoulder mobility, AASI can be particularly disabling.

Numerous studies in the past decade have increased our knowledge regarding the assessment and treatment of the shoulder (Gerber and Ganz, 1984; Cofield and Irving, 1987; Hawkins et al, 1989; Hawkins and Mohtadi, 1991b). Clinical examinations and specific tests for evaluating GH joint stability have been well documented and tested (Hawkins et al, 1989; Harryman et al, 1990; Hawkins and Mohtadi, 1991a; Hawkins and Mohtadi, 1991b) and although these tests are very good clinically at detecting instabilities

in a static, sometimes unspecific clinical setting, the question must be asked whether or not they represent good indicators of an individual's *functional* stability or instability.

Functional instability refers to the instability that an individual experiences while performing a functional activity. This activity can range from a simple task of reaching for a glass, to a more complex, challenging motion such as an overhead throw. The individual with this type of instability often presents as a challenge to the clinician because the factors involved in performing the function that produces the instability, and likely contributes to the instability, are very difficult to reproduce and simulate with many of the typical clinical tests. These factors may include awkward, sometimes extreme GH joint positions, very fast speeds, quick reactions and reflexes, neuromuscular coordination, and endurance, to list a few.

The information gained from the clinical stability tests presently utilized are important and essential to establish a diagnosis and determine an appropriate treatment intervention. However, perhaps the addition of one or more objective functional shoulder tests which would simulate some of the functional parameters such as joint position, speed and reaction time and provide the clinician with a measurement tool of the individual's ability to perform a functional task, may lead to a better understanding of the condition of AASI and aid in facilitating a more suitable treatment intervention and a better overall functional outcome for the individual.

Similar research questions associated with knee instability syndromes have led to the development of functional performance tests such as the hop test and the figure - 8 run test (Daniel et al, 1982; Tegner et al, 1984). These tests were designed, not to replace the

clinical joint stability tests that are routinely performed, but as an additional measure providing information to the clinician about the individual's ability to use the knee joint in a manner that simulates function.

The purpose of this study was to utilize three objective functional shoulder tests (FSTs) and compare the results from these tests on subjects with AASI and subjects with normal shoulders to determine if a significant difference exists. These FST results were then compared with results of a subjective shoulder rating score (Simple Shoulder Test, [SST]) and visual analogue scales for pain and sense of instability to determine if a correlation existed between the two measures.

B. Objectives of the Study

The objectives of this study were:

1. To compare the FST results obtained from the two study groups (the experimental and control groups) to determine if a statistically significant difference occurred and if a difference was detected between the two study sample populations, which of the three FSTs was responsible for the greatest statistical difference.
2. To compare the FST results obtained from the two study groups with the subjects' corresponding results on the shoulder function rating score and visual analogue scale measures to determine if any correlation existed and if so, which of the three FSTs was responsible for the greatest correlation value.

C. Research Hypothesis

The following hypotheses were examined:

1) Subjects with AASI (the experimental group) will not perform as well as the control subjects on all of the FSTs. This will result in the following specific findings:

(a) FST 1 (Shoulder Rotation Test) - subjects with AASI (experimental subjects) will not be able to complete as many of the repeated rotation motions as the control subjects.

(b) FST 2 (Light Board Test) - subjects with AASI (experimental subjects) will not accurately touch as many lights on the light board as the control subjects.

(c) FST 3 (Overhead Throw Test) - subjects with AASI (experimental subjects) will not be able to complete as many of the overhead throws, in the 20 second time period, as the control subjects.

2) The results obtained from the FSTs will correlate satisfactorily with the shoulder function rating score.

3) The results obtained from the FSTs will correlate satisfactorily with the visual analogue scales used for rating pain and sense of instability.

In this particular study, a satisfactory correlation was defined as 0.40 and higher. This value was determined by calculating the critical value of the correlation (r -crit) at a significance level of 0.01 based on 40 study subjects. (see Appendix E for this r -crit

calculation) The absence of related research made it difficult to speculate on the relationship between functional tests in the shoulder and subjective rating scales. As a result of this, a moderate correlation coefficient was selected.

D. Definitions

Study Subjects: Volunteers who fulfilled the inclusion and exclusion criteria and participated in the study. Two groups of subjects were utilized: an experimental group (subjects with AASI) and a control group (subjects with normal shoulders).

Atraumatic Anterior Shoulder Instability (AASI): For the purpose of this study, AASI was defined as a symptomatic, increased anterior glenohumeral joint translation in the absence of any history of traumatic dislocation requiring assistance to reduce. The glenohumeral joint recurrently subluxes anteriorly up to the rim of the glenoid followed by a spontaneous reduction.

Functional Shoulder Tests (FSTs): Performance tests designed to simulate functional positions and activities of the shoulder during daily life, work and sport. The three FSTs that were utilized in this particular study were: 1) FST-1: Shoulder Rotation Test, 2) FST-2: Shoulder Light Board Test, and 3) FST-3: Overhead Throw Test. For a further description of these tests, see "Testing Procedures" in Chapter 3.

Simple Shoulder Test (SST): The subjective shoulder function rating score that was used in this study. It was developed by Lippitt in 1992 as a function-based outcome assessment

tool consisting of 12 questions derived from Neer's evaluation (Neer, 1972), the American Shoulder and Elbow Surgeons evaluation, and the most frequent complaints of patients observed in the shoulder practice at the University of Washington.

Visual Analogue Scale (VAS): A patient directed, subjective rating scale used for self-reporting of subjective experiences like pain intensity or functional limitations. (Melzak, 1983; Huskisson, 1983) The scale is made up of a straight, horizontal line, 10 cm in length. At each end of the scale there are terms which are used to describe the extremes of the variable that is being measured. Scoring of the VAS is typically done by measuring the scale in millimeters from the lower end of the scale. In this particular study, the two variables that were measured using a VAS were pain and sense of instability. (see Appendix B for an example of these two tests)

E. Inclusion Criteria

The inclusion criteria for subjects in the experimental (AASI) group were as follows:

- men and women between the ages of 16 and 35
- reported subjective history of recurrent shoulder pain and/or instability
- a positive anterior apprehension/relocation test
- a positive load and shift test (in an anterior direction)

A detailed description of the GH joint stability tests utilized in this study can be found under "Data Collection" in Chapter 3 and in Appendix A.

The inclusion criteria for subjects in the control group were as follows:

- men and women between the ages of 16 and 35
- no history of recurrent shoulder pain and/or instability
- a negative anterior apprehension/relocation test
- a negative load and shift test

F. Exclusion Criteria

The exclusion criteria for subjects in both study groups were as follows:

- surgical procedure of affected shoulder and/or shoulder girdle
- any neurological signs and/or symptoms originating from the C-spine
- history of rotator cuff tear
- history of glenohumeral joint dislocation
- history of any fracture to the shoulder and/or shoulder girdle
- history of sprain and/or separation of acromioclavicular joint
- history of sprain and/or separation of sternoclavicular joint
- symptomatic** multidirectional instability (defined as pain and/or instability in an inferior and/or posterior direction)
- inadequate active range of motion (ROM) to perform the functional tests *
- grade II (moderate) or grade III (severe) impingement signs **

* **See Chapter 3, "Data Collection" for more information on the ROM requirements and the impingement classification used in this study.

G. Limitations of the Study

The limitations of this study were as follows:

1) The most obvious limitation was with the FSTs themselves. Although careful considerations were taken in their development with respect to AASI etiology and epidemiology, they were relatively new, untested means of measuring shoulder functional performance. The absence of a "gold standard" for objective functional shoulder testing, or any functional testing of the shoulder at all, made it difficult to compare the validity prior to using the tests in this study. All appropriate steps to ensure consistency in setting up subjects and collecting the measurements were taken, as well as doing numerous practice sessions and pilot tests on the equipment itself. One examiner was responsible for taking all of the measurements (the author) and a second examiner was used as an assistant. In addition, all of the subjects' testing sessions were recorded on videotape so that any discrepancies or potential errors in data could be checked.

2) This study was dependent upon the accuracy of diagnosing the shoulder instability (AASI) being examined. Although defined as a limitation, the study's use of one expert, an orthopaedic surgeon for testing all of the subjects was considered a strength. Inter-tester reliability testing took place between the examiner (the author) and the orthopaedic surgeon, to ensure that all subjects met the inclusion/exclusion criteria and were assigned to the appropriate study group. (see Appendix F for reliability test results)

3) This study relied on the validity and reliability of the Simple Shoulder Test. Lippitt (1992) has reported only preliminary findings, which indicate that the test is sensitive and valid. However, there have been no further studies reported on the test to support these early findings. It is a commonly utilized subjective shoulder rating score and for that reason it was chosen for this study.

H. Delimitations of the Study

The delimitations of this study were as follows:

- 1) This study dealt with individuals with AASI and therefore conclusions regarding other types of shoulder instabilities may not be made.
- 2) The population that was examined was aged 16 to 35, therefore the effect of AASI on individuals outside of this age group cannot be considered.
- 3) This study compared the results from the FSTs to the Simple Shoulder Test and horizontal visual analogue scales for pain and instability, therefore comparisons to other subjective rating scores cannot be made.

I. Ethical Considerations

All subjects involved in this experiment read and signed a consent form (see Appendix D) which included an explanation of the purpose of the study and the procedures involved.

All data collection and records on these subjects remained confidential and subjects were referred to in all experiment documentation by an identification number.

The potential benefits of this experiment far outweighed any potential risks. The clinical examination that was performed was based on typical examination and testing procedures used and the three FSTs were designed to reproduce functional joint positions, muscle performance and neuromuscular patterns typically used. The only risks involved in participation of this study were joint and muscle soreness associated with normal activity.

Subjects were advised that they were free to withdraw from the study at any time without prejudice or coercion.

CHAPTER 2

REVIEW OF THE LITERATURE

The majority of the related research in this area of study is on shoulder instability itself, the etiology and epidemiology of its occurrence, and the techniques of clinical evaluation. Far fewer scientific studies have been done with respect to functional evaluation of the individual with shoulder instability. In order to understand the process of functional, performance testing, one must look towards the research that has been done in other joints.

The following literature review will be divided into three sections: (1) Atraumatic Anterior Shoulder Instability - the anatomy and biomechanics of the shoulder complex, the contribution of proprioception to shoulder instability, the classification of shoulder instability syndromes, and the epidemiology of AASI, (2) Evaluation of Shoulder Instability, and (3) Functional Evaluation of the Shoulder Joint.

I. Atraumatic Anterior Shoulder Instability

Atraumatic Anterior Shoulder Instability (AASI) is one of the most common and disabling conditions that an individual involved in overhead work and/or sports can have. The potential labral tears, ligament damage, rotator cuff injuries, fractures and neural involvement that may be associated with AASI can lead, in some cases, to the end of a working or athletic career (Warren, 1983; O'Brien et al, 1987; Jobe and Bradley, 1989; Andrew et al, 1991; Mohtadi, 1991).

A. Anatomy and Biomechanics of the Shoulder Complex

Movements of the shoulder occur as a result of a precise, coordinated interaction between four articulations: the glenohumeral, scapulothoracic, acromioclavicular and sternoclavicular joints (Reid, 1992). This complex and delicate interaction allows the shoulder significant three dimensional mobility. If altered, however, it may lead to painful, disabling syndromes such as impingement and instability (Warren, 1983; Clark and Harryman, 1992; Reid, 1992).

The bony configuration of the glenohumeral (GH) joint allows for the greatest amount of mobility of any joint in the body. The articular surface of the humerus is a superomedially oriented hemisphere that forms approximately one third of the surface of a sphere with an arc of about 120 degrees. The glenoid, in comparison, is small and shallow with half of the contour and one third of the surface area of that of the humerus (Bowen and Warren, 1991; Matsen et al, 1991). The area and the depth of the glenoid is enhanced by the fibrocartilagenous glenoid labrum which has been reported to increase the humeral head contact area to 75 percent coronally and 56 percent transversely (Cooper et al, 1992).

Several authors over the past two decades have debated the relative contributions of these articular components to GH joint stability (Sarrafian, 1983; Kronberg and Brostrom, 1990; Terry et al, 1991; Clark and Harryman, 1992). Saha (1971) felt that there were three structural components that affected the stability of the GH joint. If the longitudinal diameter of the glenoid cavity was less than 75 percent and the transverse diameter was less than 57 percent of the humeral head, he classified the glenoid cavity as being "hypoplastic" which he felt could lead to an unstable joint. He also felt that a reduced retroversion of the

humeral head and/or an anteverted glenoid tilt could increase the possibility of an anterior instability. Other authors (Kronberg and Brostrom, 1990; Soslowsky et al, 1992) have continued to investigate these early findings of Saha and in almost all cases, similar findings with respect to the contribution of the articular components of the GH joint to stability have been discovered.

In 1990, Kronberg and Brostrom investigated the differences in humeral retroversion between patients with anterior GH joint instability and normals using radiographic techniques. Their results revealed that the unstable group had a significantly smaller retroversion angle than a group of normals. Interestingly, when they categorized the unstable group according to etiology, they discovered that the atraumatic dislocators had a significantly reduced humeral retroversion when compared to the traumatic dislocators. This difference between the atraumatic and traumatic dislocators was not explained by the authors, however it raises the question about the etiology and possible anatomical contributing factors of these two different categories of instability.

Soslowsky et al in 1992, also studied the articular geometry of the GH joint. They used a technique called stereophotogrammetry and concluded that the poor anatomic stability of the GH joint was the result of a small glenoid surface area in relation to the humeral head, not because of the relative shallowness or lack of congruence of the joint.

The relationship between the articular components of the GH joint and clinical instability of the shoulder has been implied, (Bowen and Warren, 1991; Blasier et al, 1992; Clark and Harryman, 1992), however the intricacies and contributions of the other stabilizing structures of the GH joint has made it difficult to be completely conclusive. One must

question whether the articular variations are indeed "abnormal", or do they exist as a common variability in all "normal" GH joints.

The importance of the glenoid labrum to GH joint stability has varied throughout recent literature (Howell and Galinat, 1988; Bowen and Warren, 1991; Matsen et al, 1991). Initially, it was believed that the labrum significantly increased GH joint stability by deepening the concavity of the glenoid and therefore improving the humeral head to glenoid congruity. Other authors have described the labrum as a specialized portion of the anterior capsule that flattens with external rotation and serves only as an attachment of the inferior glenohumeral ligament (Sarrafian, 1983). More recent research has redefined the labrum as consisting of fibrocartilagenous tissue, distinguishable from the fibrous capsule and an important static stabilizer of the GH joint (Prodromos et al, 1990; Cooper et al, 1992). Although slight differences exist between the specific anatomical descriptions of the glenoid labrum, the function of this tissue, in all cases, has been defined as one of GH joint stability.

The capsular-ligamentous (CL) structures are the other important static constraints of the GH joint. They consist of the superior, middle and inferior GH ligaments as well as the coracohumeral ligament. There is controversy regarding the role the GH ligaments have in the stability of the shoulder due in part to the anatomical anomalies in the ligaments themselves, specifically the size of the middle portion, and the difficulty in generalizing cadaveric studies to normal physiological movement (Ferrari, 1990; O'Brien et al, 1990; Harryman et al, 1991).

Extensive research (Turkel et al, 1981; Ferrari, 1990; O'Brien et al, 1990; Malicky et al, 1996) involving ligament cutting and translation experiments, as well as anatomical and histological investigations, has concluded that the GH ligaments not only contribute to overall joint stability, but also assist in controlling "normal" joint mechanics during movement. The controversy regarding the role the CL complex plays versus that of the dynamic constraints for overall GH joint stability was tested by Turkel et al (1981); Schwartz et al, (1988); Harryman et al (1990); and Bowen and Warren (1991). Their results demonstrated that, providing the underlying CL structures were intact, severing the rotator cuff tendons did not produce GH joint subluxation or dislocation regardless of the position of the shoulder. These findings suggest an important "dynamic" stabilizing role of the CL complex in maintaining normal ball and socket joint mechanics during movement.

Other CL research has shown that with experimental translations, in order to produce a GH joint dislocation, a portion of the capsular structures on both sides of the GH joint had to be cut (Silliman and Hawkins, 1991). This has important implications for diagnosing and treating this condition. Surgical considerations must be altered to ensure the repair of both sections of the damaged capsule and conservative treatment techniques such as stretching and strengthening must be performed to protect both aspects of the joint capsule.

Two studies have defined the inferior GH ligament complex as the most significant stabilizing component of the ligament complex (O'Brien et al, 1990; Warner et al, 1992). Both groups have described this ligament as a complex of structures, consisting of an anterior and a posterior band with an axillary pouch that functionally cradles the humerus, especially in elevation.

The anterosuperior interval, or "rotator interval", consists of the CL structures between the supraspinatus and subscapularis muscles (the superior GH ligament and the coracohumeral ligament). These structures have been found to be the second most important stabilizing elements of the CL complex, particularly with respect to posterior and inferior stability (Harryman et al, 1992a).

The role of the CL complex, in maintaining GH joint congruency in an infinite variety of shoulder positions, is well defined and substantiated in the literature (Bowen and Warren, 1991). More recent studies have begun to focus on the role that these ligamentous structures may have during dynamic motions of the shoulder. Howell et al (1988), evaluated the position of the humeral head radiographically relative to the glenoid fossa while positioning the shoulder in varying amounts of horizontal flexion and extension. Their results showed that in the control group, it was only when the shoulder was in the position of maximum horizontal extension and external rotation that the humeral head was not centered in the glenoid, but rested approximately 4 millimeters posterior to the center of the glenoid cavity. In the unstable group, the humeral head demonstrated an anterior translation or no translation with horizontal extension and external rotation. They concluded that the difference was due to insufficiency in the anterior capsulolabral structures of the unstable group. Normally, the tension in these structures is sufficient to cause a posterior translation as the humeral head was "pushed" up against them.

Terry et al (1991), using a strain gauge analysis and a shoulder motion device that could accurately measure in 3 planes, evaluated the tension-sharing relationships of the static restraints of the GH joint with different GH movements and movement combinations. Their analysis demonstrated a reciprocal tension-sharing relationship amongst all ligament components and a transference of tension among these components when original and new

joint positions were compared. These findings supported the earlier concept that the static restraints have an important role in guiding and positioning the humeral head during dynamic movements.

The dynamic stabilizers of the GH joint consist mainly of the four rotator cuff muscles (supraspinatus, infraspinatus, teres minor, and subscapularis). While the rotator cuff muscles do assist in gross humeral movements, their primary function is one of dynamic stability (Bowen and Warren, 1991; Reid, 1992; Sharkey and Marder, 1995). Along with the CL complex and the "ball and socket" mechanism, these muscles function to accurately position the humeral head within the glenoid fossa throughout range of motion, ensuring that joint surface motion is predominantly rotational. Matsen et al (1991) have identified the rotator cuff as maintaining this control simply through the joint compression component of their action. Sarrafian (1983) and Clark and Harryman (1992), investigated this intimate anatomical relationship between the rotator cuff tendons and the joint capsule. They discovered that careful dissection of the cuff tendons away from the capsule left a very thin, perforated structure. If this balance, between the rotator cuff and the joint capsule, was upset, the resulting abnormal joint mechanics could lead to damage of the articular or extra-articular soft tissue. Increased humeral head translation superiorly could compromise the superior soft tissue structures while abnormal anterior, posterior or inferior humeral head translation could lead to damage of the CL or labral structures. Any of these possibilities alone or in combination could result in a clinical presentation of shoulder instability.

In addition to the static and dynamic stabilizing factors mentioned above, the GH joint has another mechanism by which it maintains its congruency. The limited joint volume and negative intra-articular pressure present at the joint allows the shoulder a certain degree of

stability as well. Speer (1995) found that during cadaveric dissections, muscle activity was not required to hold the shoulder together as long as the joint capsule was not cut. He stated that the magnitude of this negative intra-articular pressure was small, however, estimated at 20 to 30 pounds, assuming that the maximum suction pressure can be only one atmosphere pressure.

B. Contribution of Proprioception to Shoulder Joint Instability

The concept of proprioception or joint position sense, is certainly not new. Its application and importance in lower extremity joints such as the knee and ankle, are well established and clinically utilized (Barrack, 1983; Barrack, 1984). Less research has been done in the upper extremity, particularly the GH joint, to investigate the relative contribution of proprioception to GH joint stability, however, two studies have examined the deficits in proprioception that occur as a result of shoulder instability (Brunolli and Smith, 1989; Lephart, 1993).

Although the concept of proprioception is well understood, the factors which control this sensation are not. While a complete review of all of the research related to this topic is beyond the scope of this study, a summary of traditional earlier research suggested that primarily the joint receptors were responsible for proprioceptive control. Subsequent experiments have demonstrated that it is more likely the muscle receptors that mediate this sensation with secondary contributions from the joint capsule and pericapsular receptors

(Clark, 1979; Burgess, 1969; Burgess, 1982; Skinner, 1986; Baxendale, 1987; Konradsen, 1993; Grigg, 1994).

More recently, researchers have begun to study what effect proprioception has on normally functioning joints and to what extent deficits in proprioception are either caused by pathology or lead to pathology (Dvir, 1988; Barret, 1991; Corrigan, 1992; Marks, 1993). Almost all of this research has been performed on the lower extremity joints. Only two study groups, to date, have investigated this phenomena at the shoulder.

Smith and Brunolli (1989), measured shoulder kinesthesia following GH joint dislocation. Ten healthy subjects were compared to eight subjects with a history of unilateral anterior dislocation, and both study groups were tested for accuracy of angle reproduction, threshold to sensation of movement and end-range reproduction using a motor-driven shoulder wheel apparatus. Their results showed a significant difference between the injured and uninjured shoulders for all three of the tests and they concluded from these results, that kinesthetic deficits occur following GH joint dislocation and may result in abnormal neuromuscular coordination and subsequent reinjury of the shoulder. More recently, Lephart et al (1993), discovered abnormal proprioceptive sensation in their patients who had been diagnosed with unilateral instability. They measured angle reproduction using a Cybex isokinetic dynamometer.

In related research, Guanche et al (1995) examined the synergistic action of the GH joint capsule and the shoulder muscles and found that the existence of the reflex arc, from the mechanoreceptors within the GH capsule to the muscles which crossed the joint, confirmed and extended the concept of synergism between the passive (ligaments) and active

(muscles) restraints of the GH joint. These findings provided information to the clinician on the anatomical and biomechanical restraints at work about the GH joint, but also from a more clinical, treatment perspective, they reaffirmed the importance of the sequence and timing of muscle contractions for stability at the shoulder. These normal patterns and sequence of muscle contractions must be retrained in the unstable shoulder and techniques such as proprioceptive neuromuscular facilitation patterns have been shown to be useful in re-establishing these functional movement patterns (Dines and Levinson, 1995; Wilk and Arrigo, 1993).

C. Classification of Shoulder Instability Syndromes

Similar to most joints in the body, different types of shoulder instability syndromes may occur at the glenohumeral joint. A number of authors (Foster, 1983; Cofield, 1987; Hawkins et al, 1989) have attempted to describe these syndromes and have developed classification systems that assist clinicians in understanding and diagnosing the various signs and symptoms that may be present. The term "shoulder instability" encompasses many degrees of severity, direction of instability and associated factors. Matsen (1989) developed a system in which a range of shoulder instabilities were classified according to their etiology, direction and associated findings. At one end of the scale was the "TUBS" lesion, representing shoulders that have undergone a Traumatic injury, have a Unidirectional instability (usually anterior), a Bankart lesion and typically require Surgical intervention. This "torn loose" TUBS situation is in contrast to the "born loose" or AMBRI syndrome found at the other end of the spectrum, which describes the shoulder that has an Atraumatic etiology, Multidirectional instability, Bilateral shoulder findings, that responds to Rehabilitation and if surgery is indicated, it is usually an Inferior capsular shift procedure that is performed.

AASI, for the purpose of this study, was defined as a symptomatic, increased anterior glenohumeral joint translation in the absence of any history of traumatic dislocation requiring assistance to reduce. The glenohumeral joint recurrently subluxes anteriorly up to the rim of the glenoid followed by spontaneous reduction. One can see that AASI, as defined in this study, portrays characteristics of both of Matsen's shoulder instability syndromes and thus lies within the spectrum of the two extremes.

In the past decade, numerous authors have examined the GH joint relative to the various directions of instability that occur. From an anatomical perspective, authors such as Turkel et al (1981), O'Brien et al (1990), Bowen et al (1991), and Culham et al (1993), have investigated the relative contributions of various bony and soft tissue structures to different directions of GH joint instability, as well as studying the biomechanical factors that occur at the joint itself. Clinically, researchers (Foster, 1983; Cofield, 1987; Hawkins et al, 1989; Yamaguchi and Flatow, 1995) have defined shoulder instabilities into those that translate in a one plane direction at the GH joint (unidirectional) and those that translate in more than one direction (multidirectional). According to Neer and Foster (1980) and Hawkins (1989), multidirectional instability refers to a symptomatic hyperlaxity pattern of the GH joint characterized by an excessive inferior translation of the humeral head as well as excessive translation in at least one other direction. The term *symptomatic* is important to note in this definition, as a tremendous percentage of the "normal" population, upon examination, presents with an increased GH joint translation that is completely asymptomatic. This reaffirms earlier questions which have been raised regarding the definition of "normal" and "abnormal" GH joint stability. Perhaps the answer to this difficult question is simply that no "normal" parameter exists, and clinicians must base their diagnosis and treatment decisions on the clinical signs evident and the symptoms that a

patient describes. In this case, the use of an objective functional shoulder test, in addition to traditional clinical testing techniques, may assist the clinician in understanding a patient's shoulder presentation.

D. Epidemiology of AASI

The shoulder is one of the areas of the body that is frequently injured in sporting activities (Abrams, 1991; Andrews, 1994). Statistical studies have reported that 8 to 13% of athletic injuries involve the shoulder complex and injuries can occur as a result of direct or indirect trauma and/or overuse (Hill, 1983; Maylock, 1988). The most common types of shoulder injuries identified are rotator cuff and bicipital tendonitis, impingement syndromes and depending upon the sport, GH joint dislocations or subluxations (Hill, 1983; Cofield, 1984; McLeod and Andrews, 1986; Andrews, 1994). The sports that reported the highest incidence of shoulder injuries (including anterior shoulder instability) were throwing sports such as baseball, tennis and football and repetitive shoulder motion sports such as swimming. Other sports, for example, gymnastics and wrestling reported injuries to the shoulder as a result of extreme positioning and leverage forces (Andrews, 1994; Pettrone, 1995). No studies specific to the incidence of AASI in sport were found.

Nicholas et al (1977) analyzed 63 sports and developed a classification of body movements required to perform these sports. Of importance to shoulder injuries is his throwing category which he further divided into explosive, dynamic or static. An example of explosive throwing is the professional baseball pitcher who throws repetitively at maximal force for relatively short periods of time. A dynamic force is demonstrated by the repetitious activity of swimming while a static force is one in which the muscles of the

rotator cuff are required to sustain isometric contractions for maintaining an iron cross on the rings in gymnastics or a weight above the head of a weightlifter. Nicholas provided a good basic framework of the types of forces incurred on the athlete's shoulder, however his research did not provide any information regarding the incidence of specific injuries of the shoulder in various sports. In fact, very little scientific work is reported in the literature that studies the incidence of specific shoulder injuries such as AASI. The majority of information attained regarding this subject is from non statistical reports of incidence from one specific team or a group of athletes seen in a clinical setting. It would seem that with this injury becoming more prevalent in sports and resulting in more serious disabilities for athletes, more efforts should be made to establish scientific data based on controls and unbiased, appropriate subject groups.

Baseball is undoubtedly the sport with the highest reported incidence of shoulder pathology (Barnes and Tullos, 1978; Jobe and Kvitne, 1989; Abrams, 1991; Andrew et al, 1991; Fleisig et al, 1995). Several authors have evaluated pitchers and throwers and found an incidence of shoulder injury as high as 61% (Barnes and Tullos, 1978; Jobe and Radovich, 1984; Glousman and Jobe, 1988; Kvitne et al, 1995). The types of shoulder injuries reported are not as clearly defined in the literature. Classifications of "muscle strains" and "shoulder sprains" are not very informative and one can only assume that some of these non descriptive terms refer to AASI. Other sports which involve overhead throwing motions, such as football, tennis, volleyball and javelin throwing, have not been as extensively studied, however, are reporting similar incidences of shoulder injury (Dagiao et al, 1980; Garrick and Requa, 1980; Chandler et al, 1992; Ellenbecker, 1995).

Shoulder pain is the most commonly reported musculoskeletal problem seen in swimming (Dominguez, 1980; Ciullo and Stevens, 1989; Allegrucci et al, 1994). Several studies have

reported this high incidence with reports of pain ranging between 40 and 69% (Dominguez, 1980; Richardson et al, 1980; Pink and Jobe, 1995). The most commonly diagnosed injury reported amongst swimmers is shoulder impingement. Shoulder instability is the second most common injury seen. More recent studies have distinguished shoulder impingement as being primary or secondary, and it is this secondary impingement which is being associated with most swimmer's complaints. Secondary impingement is defined as a relative decrease in subacromial space as a result of GH joint instability (Allegrucci et al, 1994). These authors have suggested that this GH joint instability may develop from a disruption of the static stabilizers (ligament, labrum and capsule) or fatigue or weakness of the dynamic stabilizers (rotator cuff muscles). Thus, secondary impingement may occur as a result of rotator cuff dysfunction from fatigue or injury as well as instability due to lax static restraints. There have been no reported studies which have investigated the specific direction of humeral head translation, however, the clinical reports of rotator cuff impingement and weakness suggest primarily an increased superior translation (Hawkins and Kennedy, 1980; Jobe and Kvitne, 1989; Allegrucci et al, 1994). Jobe and Kvitne (1989) developed a classification system for overhead athletes which takes into account the overlap between impingement and instability. They discussed the difficulty in diagnosing this particular athlete because the instability is often subtle and there is rarely a history of a traumatic injury. These authors, as well as others, (Warren, 1983; Warner et al, 1990; Matsen et al, 1991) called this type of shoulder instability "silent subluxation". Warner et al (1990) reported that 68% of the shoulders that they identified with positive impingement signs also had anterior shoulder laxity which existed in the absence of any reported traumatic history of instability. In light of these more recent findings, one must question whether earlier reports of impingement amongst swimmers were in fact as a result of GH joint instability.

II. Evaluation of GH Joint Instability

The past decade has seen an increasing number of studies related to shoulder instability syndromes (Hawkins et al, 1989; Jobe and Bradley, 1989; Hawkins and Mohtadi, 1991a; Silliman and Hawkins, 1991; Bahr et al, 1995). For the clinician, one of the biggest challenges lies in accurately assessing and diagnosing the condition. In some cases, the instability may be very subtle and patients may only describe a sensation of pain and/or weakness. A compounding problem is that because this condition affects such a large athletic population, typical testing procedures may not be specific enough to reproduce the biomechanical actions of the shoulder joint during these sports.

There are many methods presently being used to assess shoulder instability. The common history, physical examination and radiographic findings continue to be the standard means of evaluation. However with rapidly improving technology and knowledge, these standard procedures are being supplemented with specific examination maneuvers, special roentgenograms, arthrography, arthrotomography, computed tomographic scanning, computed arthrotomography, magnetic resonance imaging and examination under anesthesia and arthroscopy (Cofield and Irving, 1987; Jobe and Bradley, 1989; Gusmer and Potter, 1995). (see Table II-1) These specialized tests and procedures, although helpful in identifying certain pathologies, are not routinely used because of the cost involved as well as the inherent risks that are associated with some of them.

Table II-1:
Specialized Diagnostic Testing for the Unstable Shoulder

Test	Test Evaluation
Roentgenograms	(1) bone shapes (2) position of humerus on the glenoid (3) humeral head impression fractures (4) bony changes at the glenoid rim
Stress Roentgenograms	(1) labral pathology (2) alterations in anterior-inferior capsule (3) increased joint capacity
Arthrography	refined information regarding labral abnormalities
CT Scanning	(1) bony structures (2) Hill Sach's lesions (3) bony or cartilaginous changes at the glenoid rim (4) loose bodies
Computed Arthrotomography	labral, capsular and cartilaginous changes
Examination under Anaesthesia	manipulation of potentially unstable shoulder
Arthroscopy	(1) Hill Sach's lesion and labral defects (2) glenoid cartilage (3) Bankart lesions (4) "bucket handle" labral flap (5) loose bodies or chondral fragments

As with all musculoskeletal evaluations, a concise sequence of clinical examinations and testing procedures are necessary for a thorough clinical investigation of the unstable shoulder. Based on the findings of the investigation, the condition is classified and then a treatment is determined. In the case of shoulder instabilities, experts, mostly based on clinical experience, have defined certain questions or criteria that must be acknowledged in evaluating this condition. Cofield (1987) describes one such "checklist" which includes information on four points: trauma, volition, relationship of arm position to symptoms and characteristics of the patient's joint structure. Foster (1983) has a similar system of evaluation but included questions regarding both the degree and direction of instability as well as questions relating to pain and weakness.

Before examining the stability of the shoulder joint, it is necessary to evaluate the mobility at other joints to determine if a pattern of generalized joint laxity exists. It is important to realize that shoulder instability and shoulder laxity are different entities with instability defined as a clinical condition in which translation of the humeral head in the glenoid causes discomfort and dysfunction of the shoulder, and laxity defined as the ability of the humeral head to be passively translated on the glenoid fossa (Hawkins et al, 1989; Yamaguchi and Flatow, 1995). Shoulders that are defined as "lax" are often completely asymptomatic. Although it has been shown fairly conclusively that joint laxity does not necessarily cause joint instability, the clinical pattern of overall general ligamentous laxity at various joints has been suggested to be one of the contributing factors of the overall condition (Dubs and Gschwend, 1988; Reid, 1992). Other contributing factors include a repetitive overhead shoulder stress in work or sport; weak, imbalanced supporting shoulder muscles; a history of trauma to the shoulder region; and/or an abnormal anatomical design of the GH joint articulation (Hawkins et al, 1989; Glousman, 1993; Bahr et al, 1995).

Many authors (Dubs and Gschwend, 1988; Beighton, 1989; Matsen and Harryman, 1991), have developed and agreed on a series of criteria called "the indices of hyperlaxity" which is designed to measure generalized ligamentous laxity of the whole body. They are as follows: 1) abduction of the thumb to touch the forearm with the wrist fully flexed, 2) hyperextension of the little finger metacarpophalangeal joint beyond 90 degrees, 3) elbow hyperextension beyond 10 degrees, 4) knee hyperextension beyond 10 degrees and 5) dorsiflexion of the ankle beyond 45 degrees. This pattern of laxity is used to describe the general body laxity, not an individual joint and therefore, should not be confused with descriptions of isolated joint laxity patterns. A good example is the swimmer, who has developed GH joint "laxity". This "laxity" is as a result of repetitive, extreme shoulder

motions and does not necessarily indicate a pattern of overall generalized ligamentous laxity at the other joints. It also does not necessarily mean that this individual has any symptoms of pain and/or instability.

Considerable variations have been reported by authors with respect to the contribution of laxity to instability (Neer and Foster, 1980; Blasier et al, 1992; Pettrone, 1995). These authors have stated that 4 to 7% of the general population meet the criteria for generalized ligamentous laxity and a much higher percent present with asymptomatic shoulder joint laxity. Neer and Foster (1980) observed that 50% of their patients with multidirectional instability had evidence of hyperlaxity, but Hawkins et al (1991) noted only an 8% incidence in his group. Warner et al (1992) observed hyperlaxity in 25% of their normal shoulder group, 22% of their shoulder instability group, and 10% of their shoulder impingement group. The lack of agreement amongst authors regarding the relative contribution of laxity to instability should be viewed carefully. In some cases an individual with a symptomatic shoulder instability may present with an overall physical profile of generalized ligamentous laxity. However, to make the assumption that all individuals that demonstrate this type of general laxity will develop symptomatic instability syndromes is false and could result in an improper diagnosis and treatment intervention.

Specific testing maneuvers designed to measure the degree and direction of translation at the shoulder joint can be divided into two categories; 1) translation maneuvers, and 2) apprehension testing.

A. Translation Maneuvers

The function of joint translation maneuvers is to allow the examiner, through proper fixation of one part of the joint and corresponding translation of the other part, the ability to measure the quantity and quality of movement in various directions. Because of the bony restraints on the superior aspect of the joint, the possible directions of instability measured are anterior, posterior and inferior. The amount of translation that is assessed in various directions is thought to reflect the integrity of specific CL elements (Silliman and Hawkins, 1991; Hawkins and Mohtadi, 1991b).

The common tests used include the anterior and posterior drawer tests, the load and shift maneuver, and the inferior drawer test or "sulcus" sign. Gerber and Ganz (1984) initially described the drawer tests. The tests are done with the patient positioned in supine with the affected shoulder held in 80 - 120 degrees of abduction, 0 - 20 degrees of forward flexion and 0 - 30 degrees of external rotation. The examiner stands facing the patient and fixes the patient's hand in his/her axilla. Relaxation of the affected shoulder and arm is necessary for accurate test results. With one hand stabilizing the patient's scapula, the examiner grasps, with the other hand, the patient's relaxed upper arm and draws it anteriorly or posteriorly depending on which test is being done. Gerber and Ganz (1984) described the force and system of grading movement as being similar to that used with the Lachman's test of the knee. Other authors have gone on to redefine the grading systems and this will be discussed in subsequent sections.

The load and shift maneuver, initially described by Hawkins (1991), assists the examiner in understanding both the degree and the direction of instability in one maneuver. With the patient in a seated position, the humeral head is grasped through the deltoid muscle and "loaded" by applying an inferior distraction force. The examiner then attempts to glide the humeral head anteriorly and/or posteriorly. The test is considered positive for anterior instability if an excessive anterior glide leaves a void under the posterior acromion and this movement is then categorized as Grade I (mild, less than a third), Grade II (moderate, head riding on the edge of the glenoid) or Grade III (severe, dislocated head).

The inferior drawer test, commonly referred to as the "sulcus" sign was initially described by Neer and Foster (1980). It is performed with the patient in a sitting position with the shoulder in either neutral abduction, 45 degrees of abduction or 90 degrees of abduction. A positive finding is the appearance of a sulcus between the acromion and the humeral head. Often this sulcus is palpated, using the thumb, to assess the amount of depression of the humeral head. This test was originally defined as a test for detecting inferior instability, however it is also commonly described as a means of evaluating multidirectional instability of the shoulder. This has originated from the theory that multidirectional instability occurs as a result of an increased laxity of the joint capsule.

B. Apprehension Testing

Apprehension testing is similar to translation maneuvers in that they are designed to stress the joint-supporting structures. The main difference is that with apprehension testing, the shoulder and arm are manipulated into positions that cause a passive displacement of the humeral head into a particular position that causes stress on the supporting structures.

Positive findings are indicated by pain and/or a sense of apprehension that the shoulder is going to dislocate or sublux.

The anterior apprehension test is used to diagnose symptomatic anterior instability and is performed by positioning the patient's shoulder at 90 degrees of abduction and applying an external rotation force while anterior pressure is exerted on the proximal humerus. The patient with anterior instability becomes apprehensive when the shoulder feels that it is about to "pop out" and the patient involuntarily contracts the muscle and counteracts the test maneuver.

The anterior apprehension test has been found to be a very reliable indicator of unidirectional anterior instability and is described as the hallmark for evaluating anterior instability (De Palma, 1983; Zairns and Rowe, 1984). It has also been found, however, to be positive in athletes who do not necessarily have anterior instability but have impingement syndromes which cause the subacromial soft tissues to be either compressed or under some tension in this position (Pappas et al, 1985; Norris, 1985). Perhaps this finding provides support for the theory that instability and impingement are in some cases indistinguishable. Fowler (1979) described a procedure, the relocation test or Fowler's sign, to help differentiate the etiology of the pain. After a positive anterior apprehension sign is elicited, a posterior pressure of the humeral head is applied often allowing for increased external rotation and abduction with less apprehension and pain. Either of these two findings indicates a positive test.

Posterior and inferior apprehension testing is not as commonly used and is not clearly defined in the literature. The posterior apprehension test mentioned by Kessel (1977) was

found by Gerber and Ganz to be inconsistent in detecting posterior subluxations. It was their impression that it was "this absence of any reliable clinical tests to identify posterior shoulder subluxations with certainty which may have contributed to its low rate of detection". Reid (1992) described a maneuver called the Posterior Subluxation Flexion test which demonstrated posterior subluxation by positioning the patient's arm in forward flexion and internal rotation and directing a posterior force along the axis of the humerus. Patients with instability in this direction frequently sublux just with forward flexion. A positive confirmation of the suspected instability is palpation of the reduction of the humeral head, often with a quick snap, as the arm is brought back to the neutral position.

All of the translation and apprehension maneuvers described above are based on principles of anatomy and joint mechanics, however the question of how well they can accurately detect the instabilities remains unanswered. Despite well thought out grading systems, there is a tremendous amount of subjective interpretation of the degree of humeral head translation that occurs. Variabilities in the subject's shoulder size and the relative strength and expertise of the examiner also contribute to the questions of validity and reliability of these tests. In addition, there is often disagreement or lack of understanding of what constitutes a "normal" amount of GH joint translation and what is "abnormal". In the last decade, researchers have begun to recognize that there is considerable variability in the amount of joint translation amongst a normal population and in fact some of these normal, asymptomatic shoulders present with more "clinical" instability than those patients who are diagnosed with a shoulder instability (Hawkins and Mohtadi, 1991a; Harryman et al, 1992b).

Norris (1985) and Maki (1988) in two separate studies, used cineradiographic techniques to evaluate the amount of humeral head translation that occurred under anaesthesia in

"normal" subjects. They discovered that there was relatively little anterior translation but up to 50% of the diameter of the humeral head translated posteriorly. The position in which they assessed the shoulder was 70 - 90 degrees of abduction with the arm in the plane of the scapula.

In 1988, Schwartz et al did a series of cadaveric shoulder studies and found that there was no significant difference in anterior or posterior translation in different positions of horizontal flexion and extension at 90 degrees of shoulder abduction. This finding is supported by Hawkins and Abrams (1988) and Harryman et al (1992) who used an electromagnetic spatial tracking device to measure GH joint translations. Both of these authors documented the net translations associated with clinical anterior, posterior and inferior laxity tests in their respective "normal" samples, in millimeters. They were also able to calculate the percentage translations of the centre of the humeral head relative to the glenoid. Harryman et al reported considerably higher percentages of humeral head translation than Hawkins and Abrams and therefore concluded that one had to be cautious in using the values from GH joint laxity tests, given that normals could demonstrate considerable translation of the GH joint.

Hawkins and Abrams (1988) also tested a group of 10 anterior and multidirectionally unstable shoulders and found that this group demonstrated almost twice as much humeral head translation in all directions when compared to the control subjects.

Gerber and Ganz in 1984 demonstrated radiographically that patients with anterior and posterior instability had increased humeral head translations using the anterior and posterior

drawer test. Their research was done on relatively few subjects and did not involve specific measurements, however it remains one of the only studies that produced objective data.

As a result of these various authors' investigations, a series of grading systems used to classify or describe the amount of humeral head translation that occurs was developed. Hawkins and Mohtadi in 1991 developed a grading system to be used with the load and shift maneuver and Hawkins and Abrams (1988) developed a similar system to describe the translation with an inferior drawer test. See Figures II-1 and II-2. Although the concept and utilization of a grading system to quantify humeral head translation is important and essential for proper evaluation of the shoulder, the question that remains unanswered is at what point, on these grading systems, do individuals become symptomatic. Earlier research demonstrated a fairly wide variability in humeral head translation amongst "normals". In spite of subsequent studies that found patients with instabilities to have slightly greater humeral head translations, there continues to be an unclear distinction between the two populations and this is further complicated by the population of individuals with hyperlaxity syndromes.

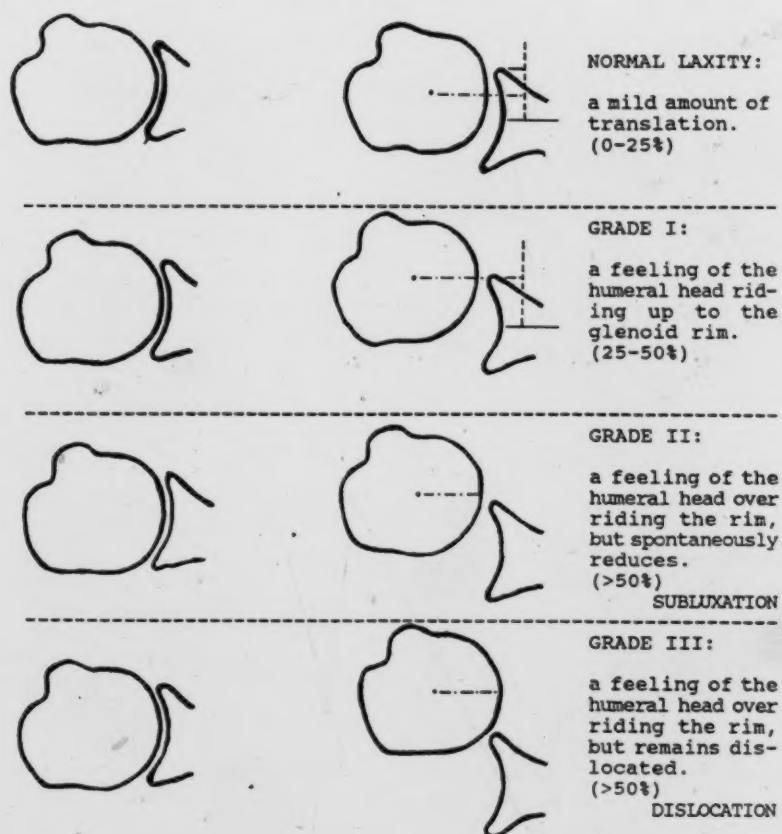


Figure II-1: Hawkins and Mohtadi's (1991b) grading system for anterior/posterior translation testing of the GH joint

Normal	The humeral head translates < 1 cm below the acromion (0-25%)
Grade I	The humeral head translates > 1 cm, but < 2 cm below the acromion (25-50%)
Grade II	The humeral head translates > 2 cm below the acromion (>50%)

Figure II-2: Hawkins and Abrams (1988) grading system for inferior translation testing of the GH joint

There does not appear to be an easy solution to the difficult challenge of measuring humeral head translation in patients. Despite well thought out testing techniques and scientifically developed grading systems, GH joint laxity tests fall victim to the subjectivity and expertise of the examiner. Another question, with respect to GH joint stability testing, which is not addressed in the literature but extremely pertinent to this particular study, is whether these tests are specific enough and/or sensitive enough to detect subtle instabilities in individuals involved in overhead work or sporting activities. These individuals present an interesting problem to the clinician in that some of these typical tests may not be challenging or provocative enough to reproduce that individual's symptoms. When one considers the inherent biomechanics of sports that have a high incidence of shoulder instabilities, the consistent findings include awkward, sometimes very extreme joint positions, very fast, explosive forces and tremendous repetitive stresses. These sport-specific demands on the athlete's shoulder are certainly atypical from those of the normally examined population with shoulder complaints and perhaps need to be considered differently. This is not to suggest that the typical stability tests done are ineffective for the athlete's shoulder and certainly a skilled clinician would consider the specific biomechanics of the athlete and modify the tests accordingly. However, if one considers the baseball pitcher and recalls that during the acceleration phase, the shoulder moves from an extreme external rotation position to a full internal rotation position at 1800-2300 degrees/second, it is difficult to imagine being able to modify any stability test to match this degree of specificity (Andrews and Wilk, 1994; Fleisig et al, 1994). Thus it would seem prudent to develop functional, performance tests that would incorporate some of these variables of sport-specificity such as position, speed, muscle performance, balance and coordination. The combination of clinical GH joint stability testing and functional performance testing is an exciting one which may assist in the evaluation of this challenging condition.

III. Functional Evaluation of Shoulder Instability

The area of functional testing of the unstable shoulder has produced very few, if any, scientific studies. The majority of functional tests presently utilized are not designed for specific conditions such as AASI, but rather are intended to be used for a variety of shoulder conditions. Most are presented in the form of subjective questionnaires which do not address function separately but instead include it with reports of pain, mobility and strength. Objective and/or performance tests of the shoulder, in general, are very rarely reported in the literature.

The evaluation of function in all dimensions of medicine has proven to be difficult. As a result, its "measure" is rarely "taken" during an assessment but more often is implied. Evaluating hard measures such as ROM, strength and stability are not only easier, they also satisfy the clinician's need to grade and interpret patient's signs and symptoms in order to determine a diagnosis, or determine an outcome following a treatment intervention. This process of evaluation has been well documented and accepted (Foster, 1983; Gerber and Ganz, 1984; Cofield and Irving, 1987; Hawkins et al, 1989), however, it often omits a very important consideration in determining the overall outcome of the individual. The patient's concept of a "good result" or a "good outcome" is rarely correlated with a grade five strength rating or "normal" ROM. Instead, it is the ability to return to the sport and/or activity and day-to-day life occurrences. Authors have categorized this "return to prior sport or activity" as function or functional outcome (Constant and Murley, 1987; Lippitt et al, 1992). The means by which this very important component of overall outcome is measured however is not well researched or understood.

A. Definitions of Shoulder Function and Functional Outcomes

The first step in establishing a measure of outcome is to define and standardize the factor which is being measured (Keller, 1992). Throughout the literature, shoulder function is defined not as a separate entity but rather as what it represents or what it is composed of. As a result, function has taken on different meanings and interpretations dependent upon the author and shoulder condition being investigated. The following section will present the various authors' definitions of "function" as it relates to the shoulder.

Constant et al in 1987 described "A Clinical Method of Functional Assessment of the Shoulder" which has become one of the most commonly used functional scores today. The method uses a 100-point scoring system which consists of a number of individual parameters which together are believed to describe or rather represent the "amount" of function that individual has. The individual parameters of this overall "function" are pain, activities of daily living (ADL), ROM, and power.

The American Shoulder and Elbow Surgeons Society (ASES) devised a form in 1982 to evaluate a patient's pain, motion, strength, stability and function. In this assessment form, function is measured individually as one of the five parameters and is not believed to be the culmination of the other four parameters. Function in this form, is defined and measured according to the ability to perform twelve ADL with four possible rankings: normal function, mild compromise of function, with difficulty, or unable to function.

Lippitt et al (1992) in their work, "A Practical Tool for Evaluating Function: The Simple Shoulder Test (SST)", describe function of the shoulder as the ultimate indication of its "wellness". They recognize that measures such as ROM and strength, although important to the clinician, have little significance to the patient who is lacking the ability to perform activities of daily life. They define function as an integration of ROM, strength, stability and comfort and have devised the SST around measurements of these individual parameters. Similar to the ASES form, questions which are related to this "function" are derived primarily from sporting activities and activities of daily life.

Rowe in 1978 looked at the long term end-result of patients' who had undergone the Bankart procedure. He devised an evaluation form which measured stability, motion and function, once again defining function in terms of the ability to perform activities of daily life.

The UCLA Shoulder Score defines function as one of the "important rating criteria" of overall shoulder function along with pain, motion, strength and patient satisfaction. Consistent with other outcome scores, it grades the "amount" of function according to ADL. It is one of the few scoring systems that asks patients whether or not they are satisfied with the outcome of their shoulder. This however, is addressed separately from the questions regarding function.

B. Specific Functional Tests

Over the past two decades, there has been an increasing amount of emphasis put on measuring outcomes of various treatment and surgical interventions used for different

shoulder conditions (Keller, 1992). Numerous evaluation and scoring systems have been developed to give clinicians an indication of their patients' "functional" outcome. As mentioned in the previous section, the definition of "function" relative to the shoulder is not clearly defined. However how it is measured and what it is believed to represent within the various rating scales is fairly consistent. No recorded data on the reliability and/or validity of the shoulder function scores was found in the literature. How the various authors decided upon the individual parameters that they chose to include in their test and specifically how they decided upon the weighting of these parameters is not known. The following section will describe the rating scales presently being used to measure functional outcome of the shoulder.

The Constant Score uses a numerical 100-point scoring system which records individual parameters and an overall clinical functional assessment. It can be used with any shoulder condition as it was designed entirely independent of a specific diagnosis. The hundred points are divided into 35 for the subjective assessment (patient questionnaire) and 65 for the objective assessment (examiner's measurement of the patient's range of motion and strength). Patients are asked to rate the amount of pain they experience during daily activities with the terms severe, moderate, mild or none representing a deduction from 15 of 15, 10, 5 or 0 accordingly. Activities of daily life make up 20 of the 35 subjective assessment points and are represented by the ability to work, ability to sleep and at what level of the body they are able to use their shoulder to perform activities. Active ROM of shoulder flexion, abduction, internal and external rotation is measured, with each movement representing a maximum of 10 points if it is within its established normal limits. The scores for flexion and abduction represent the amount of elevation that a patient can actively do without pain. Internal and external rotation are measured, not in standard terms, but in functional positions combined with extension/adduction and flexion/abduction

respectively. Strength is recorded as the amount of weight, up to a maximum of 25 pounds, that a patient can hold in 90 degrees of abduction with the arm in the plane of the scapula. The amount of time that the patient must hold the weight in this position is not defined in this rating scale and as a result may lead to inconsistencies in interpretation and measurements of this parameter.

One obvious question which arises in studying Constant's Functional Shoulder Assessment is with respect to the designation of points for each value. On what basis did he decide that pain should be allocated 15 out of 100 possible points, or 20 out of 100 points was enough to represent the ability to perform activities of daily life. A second concern with this functional score is the designated questions he has chosen to represent "function". He has the "ability to work", the "performance of recreational activities", the "ability to sleep", and the "ability to work at varying levels" as the four questions in this section and allocates a maximum of four points for the first two questions, two points for the third, and ten points for the last question. There is no report within his work as to how the weighting of these values was determined.

Lippitt et al (1992) developed the Simple Shoulder Test as a "function-based outcome assessment" tool consisting of 12 questions from Neer's evaluation (1972), the American Shoulder and Elbow Surgeons evaluation and the most frequent complaints of patients observed in the shoulder practice at the University of Washington. As mentioned in the previous section, shoulder "functions" are defined according to ADL and patients are asked whether or not they are able to perform these particular functions. The only necessary equipment are 1, 8 and 20 lb weights, and the simplicity of the test allows it to be administered by the patient. Lippitt felt that one of the strong advantages of his shoulder score was this simplicity and by allowing the patient to fill out the form independent of an

examiner, it would eliminate the potential for bias to occur. He demonstrated through preliminary data that the SST is a "quick, practical, and inexpensive method for assessing shoulder function in a busy clinical setting." They found that 81 healthy subjects with normal shoulders could perform all of the SST functions. Of the 81 patients studied, less than 5 percent could not perform one of the questions numbered 7, 8 or 10. (see Figure III-1) It is important to note that the age group that was used in this study was 60 - 70 years of age therefore it is expected that a younger, normal population would not experience the same difficulties. Over a period of 18 months, Lippitt and his associates used the SST on approximately 250 new patients with a variety of shoulder pathologies, including shoulder instability. The SST results in these patients compared to a normal control population were found to be radically different. They concluded that despite its simplicity, the SST appeared to be sensitive enough to demonstrate functional impairment effectively in each of these common shoulder disorders.

The American Shoulder and Elbow Surgeons Society (ASES) form, although often used to measure functional outcome, was actually designed as a documentation form that allowed the examination and the documentation of the findings to be standardized, not rated. This is different from the intention of other functional shoulder scales which are designed to rate patients on a point system and draw conclusions and comparisons amongst other populations. The purpose of the ASES form is to provide documentation on an individual patient and to draw comparisons as that same individual proceeds through a treatment process or post-intervention. The components of the document are pain, motion, strength, stability and function and with the exception of the motion parameter, the rating system is a 0 - 5 pattern with 5 denoting normal, 4 being mild compromise or some limitation and so on. Range of motion is assessed in terms of active flexion in sitting, passive internal rotation and active external rotation in a neutral and abducted arm position. Points are given

according to the amount of movement in degrees. The ASES evaluation form is one of the few tests which measures stability not only according to the amount of instability but also the direction of instability. The authors recognize that the presence of instability does not always represent a functional impairment and therefore this measurement contributes more to the diagnosis than to the overall description of function. Function is assessed by asking a series of questions about performing daily activities and the responses range from being unable to perform (0) to normal functioning (4).

The UCLA shoulder outcome test uses a 35 point scoring system to measure pain, function, motion, strength and patient satisfaction. Pain and function are each allocated a maximum of 10 points if no impairments are noted while motion, strength and patient satisfaction are each allocated a maximum of 5 points. "Excellent" results are those with scores of 34 and 35, "good" results are 29 - 33 and "poor" results are scores of less than 29. The function parameter, similar to other scoring systems, measures the ability of the individual to perform daily activities. Motion is represented by the amount of available active forward flexion and strength of forward flexion is assessed manually using the standard manual muscle testing rating of 5 = normal, 4 = good and so on. Patient satisfaction is recorded as either "satisfied and better" or "not satisfied and worse" and the point allocation is 5 or 0 accordingly. As in previously described tests, the reasoning for allocation of certain values out of a maximum of 35 is not clearly defined. This test allocates 10 out of 35 points for the measure of function which is a higher percentage than most, however it allocates a relatively low percentage to patient satisfaction (5 of 35) which is seemingly very important in a functional outcome score.

The Walch-Duplay Rating System (Walch, 1987) is a rating system of anterior instability of the shoulder which was modified from Rowe's original rating sheet. It is based on

statistical analysis that has shown that the influence of stability in Rowe's system is so overwhelming that clear-cut differences in functional results are masked by the allocation of 50% of the possible points to stability alone. The authors of this modified scale have therefore placed more emphasis on functional recovery including questions on performance in sports and/or daily activities. The rating scale also considers stability, pain and mobility with each of the 4 categories being allocated a maximum of 25 points. It is one of the few rating scales that has been established for a very specific patient population and as a result, it has questions and categories that are relevant only to this condition. However, until further research is done to determine if general functional rating scales are sensitive enough for a variety of shoulder conditions, rating systems such as this one should not be discounted.

Tibone and Bradley (1992) developed a specific rating scale to meet the special demands of the athlete's shoulder; the "Athletic Shoulder Outcome Rating Scale". They felt that the existing rating scales when applied to the athlete's shoulder, did not accurately represent the true outcome needed by this population. They therefore developed a new system which is divided into competitive level, diagnosis, subjective and objective parameters. The subjective parameters are: 1) competitive pain symptoms, 2) strength/endurance, 3) stability, 4) intensity, and 5) performance. Objective parameters are limited to ROM in specific positions. The separate parameters are weighted dependent upon their importance to overall outcome with a maximum overall score of 100. Once again, the issue of what parameters constitute function and best represent the measure of outcome is raised. In this particular rating scale, the authors have attempted to design a scale which is more appropriate for an athletic population choosing categories such as strength and endurance, stability and performance. There is no question that these are extremely important components in overall athletic function. However, in the objective section of this rating

scale, they have selected ROM as the representative parameter and have designated a maximum of 10 points of 100 for "normal". Why ROM was selected and how it was determined that it represented 10% of an outcome measure is not clear.

In summary, the available literature on measuring function at the shoulder has demonstrated that no clear definition of what shoulder function is exists, however most authors believe that function can be represented by the ability to perform basic activities of daily life. The emphasis or weighting that is placed on function amongst the different rating scales is extremely variable, indicating that despite agreeing on what function may be, there is little agreement on how important it is in the overall outcome of the patient. Tables II-3 and II-4 provide a comparative analysis of the functional outcome scales of the shoulder and a comparison of the manner in which the different authors represent function in their scales.

Table II-2: Functional Outcome Tests with Corresponding Function Measure

SCALE	FUNCTION
Constant Score	(1) ability to work, sleep, work at level (waist, neck, head) (2) recreational activities
Simple Shoulder Test	(1) ability to sleep, lift arm, toss softball, wash, dress, work
ASES Test	(1) ability to work, dress, wash, eat, sleep and do usual sport
UCLA Test	(1) ability to use arm and do housework, self care, light activities
Neer Test	(1) ability to do ADL
Rowe Test	(1) ability to do work and sport
WDRR Test	(1) ability to do work and sport
ASORS	(1) ability to perform at same level of activity

Table II-3 Comparative Analysis of Functional Outcome Scales of the Shoulder

SCALE	SUBJECTIVE	OBJECTIVE	TYPE	ADMINISTERED BY	EQUIPMENT	Dx DEPENDENT
Constant Score	pain function	motion strength	100 pt. question	patient/examiner	goniometer 0-25 lb. weights	no
Simple Shoulder Test	function		12 yes/no	patient	1, 8 & 20 lb. weights	no
ASES Test	pain function	motion strength stability	0-5 ranks	patient/examiner	goniometer 10 & 15 lb. weights	no
Neer Test	pain pt. satisfaction	motion strength	satisfied or not	patient/examiner	goniometer	yes
Rowe Test	function	motion stability	100 pt. question	patient/examiner		yes
WDRR Test	pain function	motion stability	100 pt. question	patient/examiner		yes
ASORS	competitive pain strength/endurance stability intensity	motion	100 pt. question	patient/examiner		no

Several questions arise in examining these shoulder functional rating scales. The most obvious one being in the definition of function itself. The overwhelming consensus amongst authors that function is represented by the ability to perform ADL leaves the reader wondering about the applicability of these tests to "abnormal" populations such as athletes, disabled individuals and the elderly. Clearly these "functions" are important and essential, however to assume that they represent the functional "goals" of all patients is incorrect. Outcome research has demonstrated that clinicians do not always know what patients consider "functionally" important in certain conditions or following surgeries. James Wright (Keller, 1992) asked a series of patients with arthritic hips to list the problems that bothered them the most on a daily basis. Two complaints, difficulty with sexual function and night pain were most frequently mentioned. Interestingly, neither of these complaints appear on any of the existing hip rating scales. Examples like these reinforce the importance of involving and asking patients what their expectations are and how they would define optimal function.

Another limitation observed in reviewing the existing functional evaluations of the shoulder is the absence of objective functional testing. All of the scoring systems reviewed measure function subjectively in a questionnaire form. Only the Constant Score attempts to reproduce "functional" positions in objectively evaluating the motions of internal and external rotation. Undoubtedly there is a need for subjective reporting by the patient on parameters such as pain and function. However, it would seem beneficial, not only for the clinician but also for the patient, to be able to concretely measure some of these indices of function as well. A test which would incorporate things such as functional positions or movement patterns, specific strength and endurance demands relative to the individual's needs and activities which would necessitate coordinated muscle actions and joint stability

would provide the clinician with a much better indication of function than separate measurements of ROM, strength and joint stability.

C. Functional/Performance Evaluations of the Shoulder

As previously mentioned, the area of functional or performance testing of the shoulder is extremely new and therefore there are no reports in the literature. With the explosion of knowledge and technology in the evaluation and treatment of the shoulder joint over the past decade, it is expected that this type of testing will soon follow.

A case has been made earlier as to what this type of testing may be beneficial for patients with different shoulder pathologies. If one considers the specific case of a patient with AASI and recalls the epidemiological reports which find a high incidence of occurrence amongst overhead athletes, these types of performance tests become even more applicable. The typical questions pertaining to ADL, or ROM and strength measures may not be specific enough and/or sensitive enough for this population who needs their shoulder joint to function in sometimes very extreme, awkward positions at high, repetitive speeds. These same conditions are often required by the individual whose occupation involves overhead work.

The development of a functional test for the unstable shoulder is challenging for a number of reasons, least of which, the absence of a "gold standard" with which to compare. Authors have attempted to develop performance tests for various conditions, however, the most researched joint of the body that utilizes these types of tests is the knee (Tegner et al, 1986). The knee joint, particularly with respect to stability, has received a tremendous

amount of attention in the literature (Hughston et al, 1976; Reid, 1992). Authors who have done investigations on the shoulder joint have often looked to the studies on the knee and drawn comparisons. The development of the drawer tests of the shoulder by Gerber and Ganz (1984), is in part as a result of the drawer tests established at the knee. Instability of the knee joint has also been proven to be one of the most disabling conditions that an athlete may have, similar to the affect that the overhead athlete has with an unstable shoulder.

Performance tests, which simulate components of sports have been devised to evaluate functional losses after ligament injuries. These tests provide objective data that can be quantitatively measured. Tests such as the 40 yard shuttle run which involves acceleration, deceleration and reversal of direction situations have provided the clinician with normative data from which to compare patients with lax knee ligaments. Tegner et al (1986) developed the well known hop test and figure of 8 tests which are designed to reproduce the sport-specific situations of many athletes. He observed that only 35% to 46% of ACL-deficient subjects performed normally on the figure of 8 test, however, most of the patients achieved normal values on the 1 leg hop test. This example demonstrates that even a well thought out test which simulates a specific component of activity, is not without its faults. Some of the reasons why a performance test may not show the functional limitations of the patient include: 1) the nature of the test itself, 2) the test is performed in a safe environment instead of a playing field, 3) there are no opponents or objects to undermine the participant's concentration, and 4) the test may involve a single repetition when in a real situation the athlete must perform that activity several times. These are all important considerations in developing a functional test.

IV. Summary

In summary, a review of the literature on the topic of functional performance testing of the unstable shoulder supports the need for further investigation. There is a substantial amount of research that has shown that the condition of AASI is indeed a disabling one, affecting primarily overhead athletes and individuals who must work with their arm above their head. The anatomy of the GH joint itself, plus the biomechanical demands placed on the shoulder during these activities are two of the main reasons why this condition occurs, however continued research into its etiology and epidemiology is needed.

Numerous studies in the past decade have increased our knowledge regarding the evaluation of the unstable shoulder (Cofield and Irving, 1987; Hawkins et al, 1989; Hawkin and Mohtadi, 1991b; Bahr et al, 1995). Translation maneuvers and apprehension techniques have been well documented and tested, however, there are certain questions with respect to these tests which remain unanswered. First of all, the questions of validity and reliability abound. The significant muscularity surrounding the joint and subsequent lack of proximal bony stabilization, makes the subjective interpretation of the degree of humeral head translation difficult. To manually standardize the force of translation and then in turn accurately and reliably identify the resulting movement is also very challenging. A second consideration with respect to clinical stability testing is the absence of a defined "normal" for GH joint translation. Tremendous variations amongst shoulders of a normal population have been identified resulting in some authors questioning typical grading systems. Although refinements have been made in this area, it is still not known what degree of instability is likely to produce symptoms. A third question which may be asked is how specific and sensitive are these clinical stability tests in detecting subtle instabilities in individuals which experience instability during forceful, high velocity activities in abnormal

joint positions. If AASI is reported to be most prevalent amongst populations that are involved in these types of activities, are these typical stability tests sufficient enough to bring the clinician to an accurate diagnosis?

Finally, reviewing the present manner in which function is evaluated at the shoulder, reveals that almost all authors define "function" in terms of the ability to perform ADL. The weighting or emphasis that each author placed on function relative to overall outcome varies considerably. The area of functional performance testing of the shoulder joint is not addressed in the research however comparable joints such as the knee have utilized these tests in the evaluation of functional losses or limitations following ligament injuries.

The above literature review has provided the following conclusions: 1) AASI is a disabling condition that affects individuals in overhead activities, 2) the present methods of evaluating GH joint stability, although effective, may not be sufficient to detect instabilities in these individuals, and 3) there is a need to define function as it relates to the shoulder and then once defined, 4) develop a means of measuring it.

CHAPTER 3

METHODS AND PROCEDURES

A. Study Participants

Participants in this study were men and women between the ages of 16 and 35. A review of the literature shows men and women equally afflicted with atraumatic anterior shoulder instability. (Hawkins and Abrams, 1989; Bahr et al, 1995), therefore both genders were included in this particular study. The age guideline was chosen as it reflects the majority of individuals diagnosed with this condition. There has also been some reported research that suggests that after the age of 35, there may be bony and soft tissue changes of the shoulder girdle region, particularly if there has been a history of instability and/or impingement, that may interfere with overall shoulder functioning (Hawkins and Hobeika, 1983; Glousman, 1993). In order to minimize the potential effects of these anatomical changes, subjects over the age of 35 were excluded.

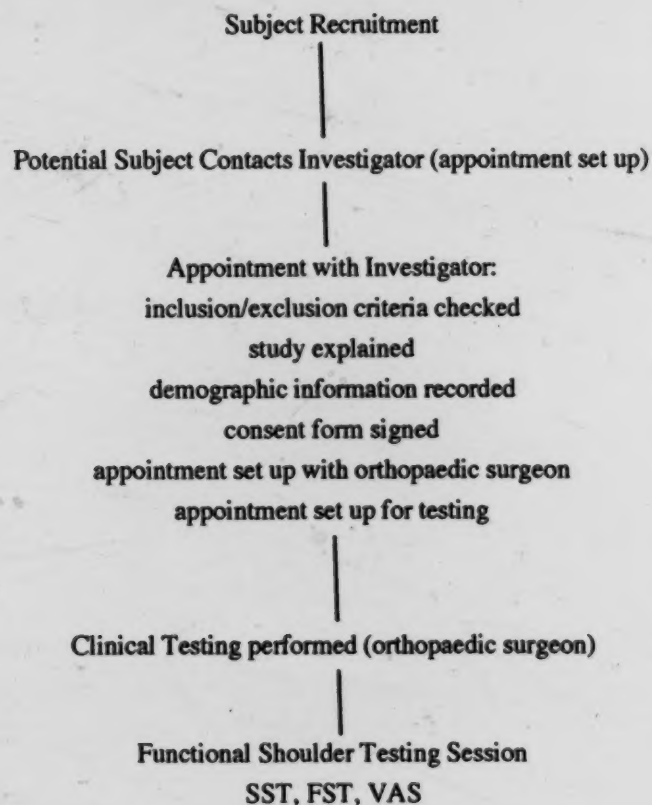
As previously mentioned, subjects were assigned to one of two study groups: the experimental group or the control group. The inclusion and exclusion criteria that subjects' had to successfully meet for these two groups are listed in Chapter 1. As this study dealt with two specific populations, randomization procedures were not performed.

B. Sample Size

Because the FSTs utilized in this study were new, and there was no data on their variability, a post hoc test on effect size was performed to determine the appropriate sample size. Based on the test, forty subjects were selected, consisting of 20 subjects in each of the two study groups. The gender distribution of each study group was 13 males and 7 females in the control group, and 16 males and 4 females in the experimental group. See Appendix G for these sample size calculations.

C. Data Collection

The order in which data was collected in this study was as follows:



C-1. Subject Recruitment

Subjects with a history of AASI were referred to one physical therapist (the author) at the Glen Sather Sports Medicine Clinic (GSSMC) by physicians and physiotherapists at the same facility. (see Appendix C for a copy of the Recruitment letter) Control group subjects were recruited in the same manner as the experimental subjects and consisted of patients and acquaintances of the staff at the GSSMC. In the initial session, all potential subjects underwent a brief subjective and objective examination by the author to ensure all inclusion and exclusion criteria were considered and met. These results were then compared to the results that the orthopaedic surgeon obtained during his testing session, and any subject who produced differing results was excluded from participation in this study to avoid any potential selection bias.

Once the initial selection was made, an explanation of the purpose of the study: to measure shoulder performance using three functional tests, was given, along with a description of the type of testing that the subjects would be asked to perform. All subjects were made aware that the testing was designed to measure their ability to do functional activities and because of this there was a risk of causing normal muscle soreness, pain and GH joint instability associated with these activities. It was emphasized that no subject would be expected to perform beyond what he/she felt comfortable doing and if at any time the subject wished to remove himself/herself from participation in this study, he/she could do so. If the potential subject agreed to participate at this point, he/she was given a consent form to read (see Appendix D) and after all questions had been answered, it was signed.

C-2. Demographic Data Collection

Demographic information was collected on all subjects who successfully met the inclusion and exclusion criteria. These measures were: age, sex, weight, height, activity level, occupation, and hand dominance. (see Appendix H for an example of the data collected) The activity level categories were defined as competitive, recreational, weekend and sedentary according to Seto et al's (1988) classification.

This information was collected and analyzed to determine if there was a characteristic pattern of demographics amongst subjects with AASI and to determine if, when compared to the control group, these individuals demonstrated any significant differences. Several epidemiological studies have reported a high incidence of shoulder instability amongst athletes and individuals, between the ages of 16 and 35, who were involved in overhead activities. Considering the inherent anatomical characteristics of the shoulder joint and the tremendous stress that is placed on the shoulder in these overhead positions, these findings are easily understood. This particular study demonstrated this same characteristic pattern in the sample of AASI subjects tested.

In addition to the above mentioned demographic data that was collected, four tests representative of generalized ligamentous laxity (GLL) syndromes were measured and recorded. Some joint instability syndromes (for example, multidirectional instabilities of the shoulder), have been shown to be related to an underlying pattern of GLL and although this relationship was not believed to exist between the specific shoulder instability subjects

being examined in this study, a separate measure of joint laxity was taken to ensure that this was in fact the case.

The four tests that were done were: 1) elbow hyperextension, 2) knee hyperextension, 3) thumb to wrist distance, and 4) fifth metacarpal phalangeal joint hyperextension. As range of motion testing does not necessarily reflect ligamentous laxity, these four tests were selected because the range of motion in these joints is largely limited by capsuloligamentous structures. They are also representative of both the upper and lower limb and reflect joints that are not necessarily influenced by a repetitive action such as throwing or overhead work. (Beighton and Horan, 1970; Beighton et al, 1989)

C-3. Clinical Examination

All subjects (experiment and control) underwent a clinical examination by one expert orthopaedic surgeon at the GSSMC. The purpose of this examination was to ensure that all subjects successfully met the inclusion and exclusion criteria established for this study. The results from the orthopaedic surgeons' examination were compared to those found by the author during the initial session with the potential subjects and any difference in the results recorded led to the exclusion of that particular subject. The clinical examination was divided into three sections: the stability tests, the impingement tests, and range of motion (ROM) required to perform the functional tests. (see Appendix J)

i. Stability Tests

For this part of the study, the three stability tests that were utilized were the anterior apprehension and relocation test, the load and shift test, and the sulcus sign. For a

description and an illustration of these tests, see Appendix A. According to the inclusion and exclusion criteria, subjects in the experimental group had to present with a positive anterior apprehension/relocation test and a positive load and shift test (in an anterior direction). They were allowed to demonstrate a positive sulcus sign, however, it had to be asymptomatic as symptomatic multidirectional instability (MDI) was one of the exclusion criteria of this study.

ii. Impingement Tests

"Primary impingement" is defined as a mechanical obstruction of the rotator cuff tendons under the anterior inferior one third of the acromion, the coracoacromial ligament and sometimes the acromioclavicular joint.

As has been noted previously in the "Review of the Literature", recent studies have shown a relationship between anterior shoulder instability and what is termed "secondary impingement". Secondary impingement is defined as a "relative" decrease in subacromial space as a result of GH joint instability. Allegrucci et al (1994) suggest that this GH joint instability can develop from a disruption of the static stabilizers (ligament, labrum and capsule) or fatigue or weakness of the dynamic stabilizers (rotator cuff muscles). Therefore, secondary impingement can be caused by rotator cuff dysfunction through fatigue or injury as well as instability due to lax static restraints.

Typically, patients with primary impingement present with limited shoulder motion and no clinical shoulder instability, whereas in secondary impingement, shoulders tend to have excessive amounts of motion with instability and/or pain being the primary problem.

Therefore, it was believed, and assumed, that the unstable shoulder subjects in this study, might demonstrate signs and symptoms of *secondary* impingement. Any subject who demonstrated obvious signs of primary impingement was excluded from participation in this study because the associated pain, loss of motion and possible articular changes may have altered the results. Furthermore, the absence of any instability in patients with primary impingement would preclude them from being included in the first place according to the inclusion criteria.

In an effort to quantify "impingement" for this study, the following classification system was developed and tested on all potential subjects.

Table III-1

Classification of Impingement Signs

TEST DESCRIPTION	0	I	II	III
Abduction/Internal Rotation	-	+/-	+	+
Hawkin's Test	-	+/-	+	+
ROM (painful arc)	-	-	+	+
ROM (reversed SHR)	-	-	+/-	+
Restricted Abduction	-	-	-	+

Explanation of Classification

Grade 0 = absence of any impingement signs

Grade I = mild impingement signs present (1 or 2 signs present)

Grade II = moderate impingement signs present (3 or 4 signs present)

Grade III = severe impingement signs present (5 signs present)

Mild impingement signs and symptoms have been reported as normal for the condition of AASI and therefore were considered acceptable for inclusion to participate in this particular study. Grade II and III impingement signs (as defined by this classification system) were considered unacceptable and led to exclusion.

iii. Range of Motion required to perform the functional tests

The FSTs utilized in this study demanded a certain degree of ROM at the GH joint in order to be performed. Subjects with less than this set ROM were excluded from participation as the results from their testing could have been heavily influenced by their restricted range. The GH joint positions tested were: 90 degrees abduction, 90 degrees scaption (elevation in the plane of the scapula), 90 degrees external rotation with 90 degrees abduction, and 45 degrees internal rotation with 90 degrees abduction.

C-4. Simple Shoulder Test (SST)

Prior to performing the FSTs, all subjects were asked to fill out the SST. No assistance was given other than being advised to answer the twelve questions related to shoulder function to the best of their ability. More information regarding this specific test will follow under section "D. Equipment".

C-5. Functional Shoulder Tests (FSTs)

Data was collected from the three objective FSTs. A complete description of these tests and information regarding the procedure of the testing will follow under sections "D. Equipment" and "E. Testing Procedures".

For FST-1: Shoulder Rotation Test, the data that was collected included:

- (1) GH joint internal and external rotation ranges (read off of the shoulder rotation board)
- (2) number of successful rotation repetitions (out of possible 30) completed at "Speed 1, Speed 2, and Speed 3"
- (3) number of successful rotation repetitions completed in a 20 second timed period

For FST-2: Light Board Test, the data that was collected included:

- (1) number of successful touches of illuminated lights in a 30 second period at three increasing speeds (LBT-1, LBT-2, and LBT-3)

For FST-3: Overhead Throw Test, the data that was collected included:

- (1) starting shoulder range of motion for each subject (horizontal extension and external rotation)
- (2) number of successful throws completed in a 20 second timed period

C-6. Visual Analogue Scales (VASs)

Following the completion of each of the three FSTs, subjects were asked to rate the amount of pain and sense of instability that was associated with the test by marking a point on a visual analogue scale that best represented the pain or instability.

D. Equipment

The three pieces of equipment that will be discussed in this section are the: Simple Shoulder Test (SST), the Visual Analogue Scale (VAS) and the Functional Shoulder Tests (FSTs).

D-1. Simple Shoulder Test (SST)

The SST was developed by Lippitt et al (1992) as a "function-based outcome assessment" tool consisting of twelve questions from Neer's (1972) evaluation, the American Shoulder and Elbow Surgeons evaluation, and the most frequent complaints of patients observed in the shoulder practice at the University of Washington. Subjects answer each question with either a "yes" or "no" and the score is derived by adding up the number of each type of answer. A result of 12/12 would represent a normal shoulder function and anything less than 12 represents a deficit in function. (see figure III-1: The Simple Shoulder Test)

Question	Yes	No
1. Is your shoulder comfortable with your arm at rest by your side?		
2. Does your shoulder allow you to sleep comfortably?		
3. Can you reach the small of your back to tuck in your shirt with your hand?		
4. Can you place your hand behind your head with the elbow straight out to the side?		
5. Can you place a coin on a shelf at the level of your shoulder without bending your elbow?		
6. Can you lift 1 pound/0.5 kg (a full pint container) to the level of your shoulder without bending your elbow?		
7. Can you lift 8 pounds/3.6 kg (a full gallon container) to the level of your shoulder without bending your elbow?		
8. Can you carry twenty pounds at your side with the affected extremity?		
9. Do you think you can toss a softball under-hand ten yards (9 meters) with the affected extremity?		
10. Do you think you can toss a softball over-hand twenty yards (18 meters) with the affected extremity?		
11. Can you wash the back of your opposite shoulder with the affected extremity?		
12. Would your shoulder allow you to work full-time at your regular job?		

Figure III-1: The Simple Shoulder Test

The SST was chosen for use in this study because of its simplicity, its subjective nature (therefore eliminating examiner bias) and its content of questions. Unlike similar shoulder rating scales, the SST asked questions that represented shoulder function in work settings, rest and during sporting activities. It also has been commonly used as a rating scale in previous studies of the shoulder.

Lippitt et al have demonstrated through preliminary data that the SST is a "quick, practical, and inexpensive method for assessing shoulder function in a busy clinical setting" (Lippitt et al, 1992). They found that 81 healthy subjects with normal shoulders could perform all

of the SST functions. Of the 81 patients studied, less than five percent could not perform one of the following questions: 7,8 or 10. It is important to note that the age group that was used in this study was 60 - 70 years of age therefore it was expected that a younger, normal population would not experience the same difficulties. Over a period of 18 months, Lippitt and his associates used the SST on approximately 250 new patients with one of the following common shoulder disorders: degenerative arthritis, rheumatoid arthritis, avascular necrosis, subacromial impingement, full thickness rotator cuff tears, frozen shoulder syndrome, traumatic anterior instability, and multidirectional instability. The SST results in these patients compared to a normal control population were found to be considerably different indicating that the SST was able to discriminate very well, between the groups of patients with the shoulder conditions and those with normal shoulders. They concluded that despite the simplicity of the assessment tool, the SST appeared to be sensitive enough to demonstrate functional impairment effectively in each of these common shoulder disorders. Because Lippitt et al did not include AASI, it was decided to see if the tool would similarly discriminate with this type of patient.

D-2. Visual Analogue Scale (VAS)

Two VASs were utilized in this particular study. (see Appendix B) The variables that subjects rated were the amount of pain they experienced and the sense of instability they felt during each of the three FSTs. The scales consisted of a 10 cm horizontal line with the descriptors "no pain" and "worst pain imaginable" used at either extreme for the measurement of pain and "no sense of instability" and "most severe sense of instability imaginable" for the measurement of instability. At the completion of each FST, subjects were instructed to mark a point on the line which best described how they felt during the

test. Scoring of the VAS was done by measuring the scale in millimeters from the lower end of the scale.

D-3. Functional Shoulder Tests (FSTs)

The FSTs utilized in this study were developed by the author for use in this study. The purpose of these tests was to determine and qualitatively measure the ability/inability of an individual to perform a designated functional task. It was hoped that a test which incorporated the components of common functional shoulder activities would assist in the assessment and treatment of AASI and in turn produce a better outcome for individuals with this condition.

Factors that were considered in developing the FSTs were the etiology and epidemiology of AASI, specifically looking at the type of activity performed, the position of the GH joint itself during activity, the muscular performance utilized, the dynamic versus the static nature of the activity and the neuromuscular coordination (ie. speed of movement, agility, endurance) required to perform the activity. Numerous researchers have provided information regarding these types of parameters that make up a sporting activity, and other researchers have taken these inherent characteristics of sporting activities and studied their relationship to specific joints and injury patterns (Abrams, 1991; Andrews and Wilk, 1994; Chandler et al, 1992; Hill, 1983). The author did a considerable review of this literature prior to developing the three FSTs used in this study. Unfortunately the absence of any research related to objective functional testing of the unstable shoulder made it impossible to test the validity of the FSTs used in this study. However all appropriate steps were taken

to ensure consistency in testing procedures, as well as doing numerous practice sessions and pilot tests on the equipment itself.

The three FSTs that were developed were FST-1:Shoulder Rotation Test, FST-2:Light Board Test and FST-3:Overhead Throw Test.

(1)FST-1:Shoulder Rotation Test (SRT)

The specific factors that were considered in the development of the SRT included specific GH joint position, speed and endurance. Individuals who have AASI will almost always describe a feeling of instability when their shoulder is in an abducted and externally rotated position; particularly as the position of external rotation is increased. Anatomically, this position places the greatest stress on the anterior supporting structures of the GH joint therefore it seemed essential that in order to measure the functional ability/disability of this population, this challenging joint position had to be incorporated. It was expected that subjects in the experimental group (those with AASI) would demonstrate increased apprehension moving into the abducted-externally rotated position of this test and eventually as the test became more difficult, not touch the external rotation support at all.

Two other components of the SRT that were considered in their development were speed and endurance. Studies have demonstrated that as the speed of an activity (ie. joint motion) increases, individuals with instability syndromes have greater difficulty in controlling the position of their joint and initiating stabilizing muscles to support the joint. As well, fatigue caused by muscle dysfunction or injury of the dynamic stabilizers can interfere with overall performance as an individual can no longer support the affected joint and begins to

experience pain and instability. In an attempt to distinguish these phenomena in AASI subjects, three increasing speeds were used as well as a timed 20 second test in which subjects completed as many shoulder rotation repetitions as possible. It was hypothesized that as the speed of the tests increased and as subjects did more of the repeated rotations, their performance would decrease and their feeling of pain and instability would increase.

The SRT involved a repetitive internal - external rotation movement with the GH joint positioned at 90 degrees of abduction. (see Figure III-2) The test was performed with subjects in a seated position with the arm being tested positioned in 90 degrees of abduction and 90 degrees of elbow flexion. The elbow was supported on the "elbow support" of the shoulder rotation board (SRB). The board itself was 6 feet by 3.5 feet with an axis of rotation in the center of the board. Two shoulder rotation supports extended out from this center axis and were moveable to accommodate each individual's available ROM. The rotation supports could be adjusted at 5 degree increments along an arc of 180 degrees. A spring loaded pin system secured the rotation support in place.

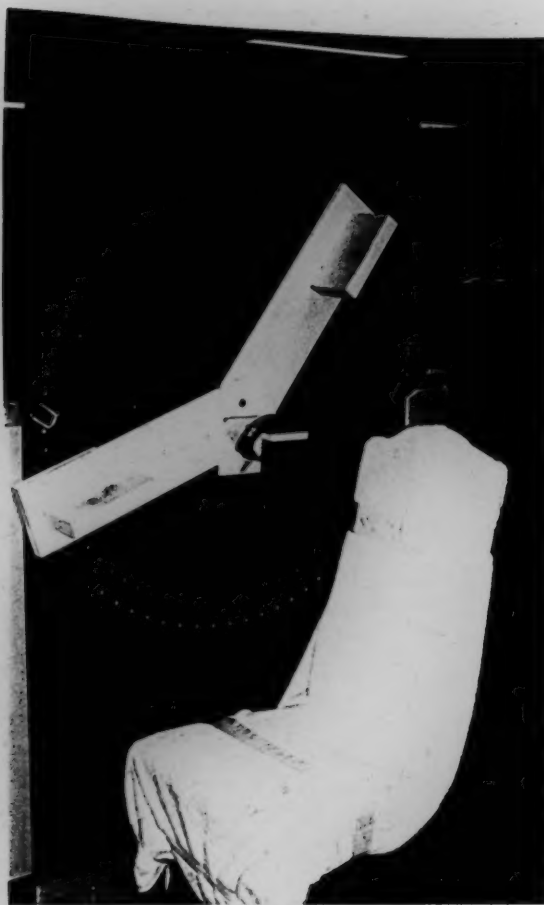


Figure III-2: Shoulder Rotation Board

Four individual tests were performed using the SRT, represented as SRT-1, SRT-2, SRT-3 and SRT-20 seconds. For the first three tests, subjects performed the rotation motion at specific speeds that are set by the examiner. A total of thirty repetitions were attempted. For the SRT-20 second test, subjects performed as many shoulder rotation motions as they could in a 20 second timed period.

(2) FST-2: Light Board Test (LBT)

The LBT involved an eye-to-arm neuromuscular coordination test in which the subject touched as many of the lights, on the light board, as they went on and off in a predetermined sequence. The "EYESPAN 2064" (manufactured by Monark America) was used in this study and it is described as an electronic light board designed to train hand-to-eye coordination at various speeds. (see Figure III-3)

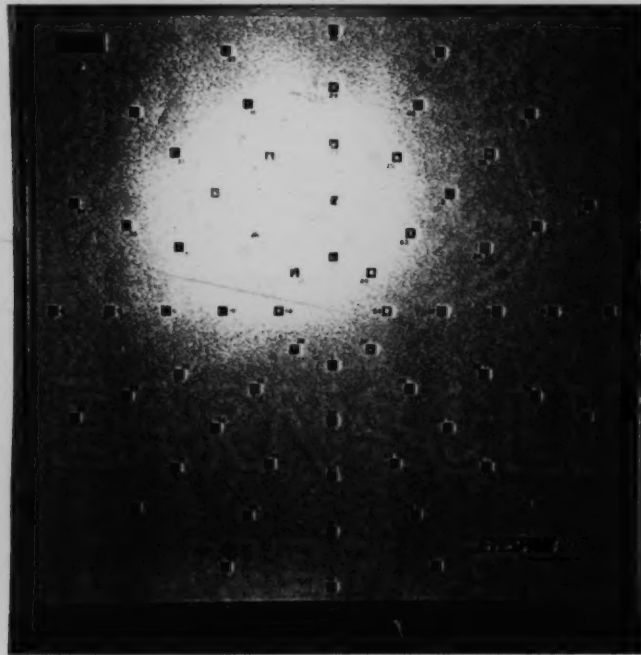


Figure III-3: Light Board

The speed at which the lights came on and off could be regulated as could the sequencing of the lights. For the purpose of this experiment, three speeds were chosen: LBT-1: 2.0 seconds, LBT-2: 1.0 seconds, and LBT-3: 0.75 seconds. Each individual test lasted for 30 seconds. The light board also contained a computerized counting system which recorded the number of successful light touches for each set sequence.

The utilization of the light board for this particular study was in an attempt to examine neuromuscular coordination in subjects with AASI which is one of the most difficult factors of any activity to measure. However, it was felt that it might be affected to some degree in this population. Rehabilitation protocols designed for patients recovering from various GH joint instability syndromes, have focused a great deal of attention on restoring normal proprioception and normal neuromuscular movement patterns. This is partly as a result of preliminary studies that are discovering deficits in these parameters following GH joint dislocations and unilateral instabilities (Smith and Brunolli, 1989; Lephart et al, 1993). Although no specific study has attempted to measure this deficit in subjects with AASI, one certainly is led to believe, from the results of these earlier studies, that the same deficit may be present in subjects with AASI.

In this particular study, it was expected that subjects in the experimental group (those with AASI) would score lower (ie. touch fewer lights on the light board) than subjects in the control group.

(3) FST-3: Overhead Throw Test (OTT)

The OTT, as the name suggests, involved a simulated overhead throwing motion. A standard softball was used and a tubing material was drilled through the ball to fix the two pieces together. This allowed for a free end of the tube which was stabilized in a door frame, at the appropriate height for each subject. This height was determined by having the subject stand against the door, with his/her arm abducted to 90 degrees and 90 degrees of

elbow flexion. The level at which the subject's wrist lined up with the door was the point where the tube end was fixed in the door. (see Figure III-4)



Figure III-4: Overhead Throw Test
(note softball attached to rubber tube)

Only one test was performed with the OTT and it consisted of subjects completing as many "throws" in a 20 second timed period as they were able.

The development of this specific FST was based on a common movement pattern that is performed during several sporting activities such as baseball, football, tennis and volleyball. Several subjective rating scores (including the SST) include it amongst their list

of functional tasks and it is an activity that regardless of one's activity level, appears to be performed at one time or another. Similar to the SRT, it incorporates the factors of specific GH joint position, repetition (endurance) and speed. Because subjects performed the throwing motion against the resistance of a tube material, there was also the added component of muscle activity being considered in this test. Several investigators have examined the specific muscle activity involved in the throwing motion (Jobe and Kvitne, 1989; Andrews and Wilk, 1994; Fleisig and Escamilla, 1994) and have noted the importance of not only the dynamic muscle balance necessary to stabilize the GH joint, but also the essential ratio of concentric and eccentric muscle contractions that must occur during the throwing motion.

E. FST Testing Procedure

E-1. Pilot Studies

Two pilot studies were completed prior to beginning this study to test the FST equipment and to ensure that measurements could be easily collected and recorded. In addition, two subjects with AASI were utilized during the development of these tests to gain information about optimal subject positioning, speeds and repetitions that were most challenging and also to obtain feedback regarding the amount of pain and sense of instability felt while performing the FSTs. These two individuals were excluded from participation in the study.

E-2. FST - All

All study subjects received the same instructions regarding the testing procedure including a reminder about the risks of the testing and the ability to cease the test at any time if needed or desired. Subjects then chose an envelope which contained the order of the three tests that they would perform. This random allocation of the FSTs was done to minimize any effect (ie. measurement) being the result of the order of the tests performed. Before each of the three tests, subjects had an opportunity to practice the activity they were about to do for a maximum time of 30 seconds. This time frame was chosen to ensure fairness amongst subjects and to allow for a final check of the equipment and subject set up. Physiologically, a 30 second work bout will primarily utilize the anaerobic ATP-PC energy system and according to Fox et al (1989), an appropriate rest time following this amount of work is 90 seconds. Therefore, in order to ensure that all subjects recovered from their practice sessions, a rest period of at least 90 seconds was taken prior to beginning each of the three FSTs.

Two examiners were present during the testing sessions, the author and an assistant. In addition, all of the FSTs for all of the study subjects were videotaped to allow for reviewing of recorded data.

E-3. FST-1: Shoulder Rotation Test (SRT)

Subjects were seated on a standard, upright chair with a backrest, with their feet supported, if necessary, to ensure that the knee joints were at a level higher than the hip joints. Standard stabilization straps were secured around the subject's chest and pelvis and then attached around the back of the chair to reduce the risk of spinal movement. The GH joint of the arm being tested, was positioned at 90 degrees of flexion to facilitate the rotation movements. Subjects were sitting perpendicular to the shoulder rotation board and the seat height was adjusted to a position where the subject's olecranon process matched the center axis point on the shoulder rotation board. The elbow of the arm being tested was supported on the elbow support of the shoulder rotation board and was fixed to the support by a standard stabilization strap. A wrist brace was worn by all subjects to prevent wrist flexion and extension movements and a "bell" was attached on either side of the subjects' second and third fingers to facilitate counting the number of rotation motions that were performed. (see Figure III-5)

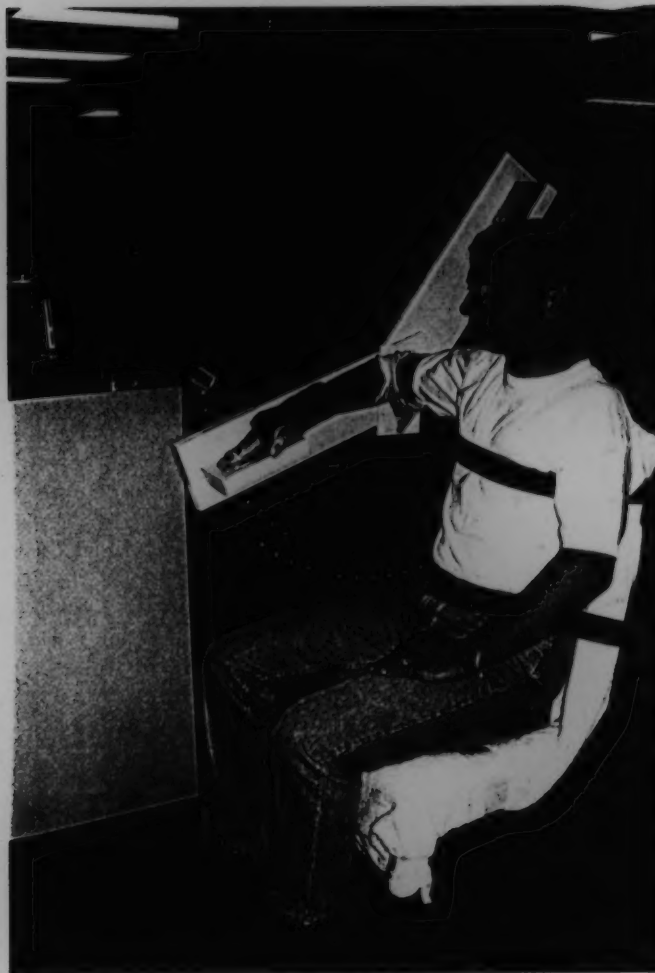


Figure III-5: Subject Performing Shoulder Rotation Test

Once positioned, the subject was asked to move his/her arm through an arc of movement from full internal rotation to full external rotation. It is important to note that the arc of movement (the shoulder rotations) that was used for each subject varied and was based on his/her own internal and external ranges of motion. This ensured that each tested individual was doing the functional movement pattern of internal to external rotation through the range of motion that he/she normally utilized. These rotation ranges of motion attained by the subject were recorded and the shoulder rotation board supports were set at these two

positions. Subjects were then instructed that the object of the SRT was to move their arm back and forth from support to support ensuring that they touched their hand to a support each time. The speed at which the motion took place was set by the ticking of a metronome and each "tick" represented an individual movement. A total of thirty repetitions was attempted at each of the designated speeds. One repetition was defined as touching both the IR support and the ER support. Thirty repetitions was chosen because of the substantial amount of research (Richardson et al, 1980; Allegrucci et al, 1994; Kvitne et al, 1995; Pettrone, 1995) that suggests that shoulder instability is often caused and exacerbated by repetitive motions and the associated fatigue that results because of this motion. In comparing testing methods which have used an isokinetic dynamometer, thirty is a common number of repetitions chosen to try and demonstrate fatigue in a muscle or group of muscles surrounding a joint (Brown et al, 1986; Reid et al, 1989).

Three speeds were used and at each speed, the number of successful contacts made on each of the supports was recorded. The three speeds were represented as: Speed 1 (1 repetition/second), Speed 2 (2 repetitions/second) and Speed 3 (4 repetitions/second). As mentioned previously, one repetition consisted of touching both the IR and the ER supports on the shoulder rotation board. The three speeds were chosen as they reflected a moderate speed, a fast speed, and a very fast speed of rotation. Again, the comparison to isokinetic testing of the shoulder has shown that several authors utilize three speeds when measuring shoulder rotation strength because they feel that the three increasing speeds (often 60, 120 and 180 degrees/sec) represent different demands and stresses on the shoulder girdle (Greenfield et al, 1990; Leroux et al, 1994; Scoville et al, 1997). From a more functional perspective, certain shoulder rotation motions involve comfortable, moderate speeds whereas in sports and/or occupations that demand repetitive, overhead rotations, the speed at which these individuals must function is often very fast. A fourth

test was done on the SRT; a 20 second timed test which involved the subject performing as many shoulder rotation motions as possible in a 20 second time frame. This test was included in an effort to measure the subject's ability to perform the shoulder rotation motions without any restrictions such as a set time frame.

All subjects had an opportunity to practice the test at the first designated speed prior to performing the real, recorded test. As previously mentioned, this involved a maximum of 30 seconds of movement followed by a 90 second recovery period, which in turn was followed by the 30 second recorded test. Subjects were instructed that the quality of their movement was extremely important and they were to resist the temptation to compensate with the rest of their body to perform the shoulder movement. They were instructed that if it was noted by either the investigator or the assistant, that they were using other areas of their body to do the activity, the test would be stopped and measurements would be recorded from that point. It was strongly emphasized to all subjects that he/she could voluntarily stop at any time during the test due to pain or any other reason if necessary. Measurements would be taken up to that point and the reason for stoppage recorded. (None of the forty subjects who performed this test had to stop). Each of the individual SRTs took place between 15 and 30 seconds dependent upon which speed was being done. In keeping with the principles of work to rest time using the anaerobic energy system, subjects were given a 90 second rest period between each test.

E-4. FST-2: Light Board Test (LBT)

For the LBT, subjects were first positioned standing, with their shoulder flexed to 90 degrees, elbow extended and index finger pointing straight. The light board was situated on a movable platform and was raised or lowered to match up the center of the board with the subject's index finger. Once this position was established, the subject's body was

on a movable platform and was raised or lowered to match up the center of the board with the subject's index finger. Once this position was established, the subject's body was turned 45 degrees, away from the light board, with the arm remaining centered on the board. This step produced the shoulder test position which was 90 degrees of elevation in the plane of the scapula (scaption). Subjects wore a wrist brace to try and minimize movement at this joint and they were stabilized against the platform on which the light board rested. As an additional stabilization, one examiner supported the subject with one hand on the subject's sternum and the other hand on his/her upper thoracic spine region. This was done in order to provide feedback to the subject regarding unwanted rotational movements. See Figure III-6.



Figure III-6: Subject Performing Light Board Test

The shoulder positioning used for this test was chosen after comparing flexion and scaption in one of the pilot tests. Both of the subjects tested, who were diagnosed with AASI, found the reaching and moving patterns more difficult when their arm was put in the plane of the scapula. This finding supported much of the literature that states that individuals with shoulder instabilities have more difficulty (and symptoms) with doing activities in positions that take the shoulder joint into abduction and horizontal extension (Perry, 1983; Bassett, 1988; Andrews and Wilk, 1994). From a functional point of view, the plane of the scapula represents the most commonly used functional position of use in ADL, work and sporting activities.

Three individual tests were performed, represented as: LBT-1, LBT-2, and LBT-3. Each test lasted 30 seconds and the sequence of the lights was pre-set and identical for each subject. The tests differed in the speed at which the lights came on and off. For LBT-1, it was every 2.0 seconds, LBT-2 was every 1.0 second and LBT-3 was every 0.75 second. Randomization of the three individual tests was not possible with this particular light board therefore all subjects performed the three tests in order. The light board contained a computerized counting system which recorded the number of successful touches for each set sequence. This was the number that was recorded from each test.

As in the SRT, subjects were instructed on the proper technique of performing the test and were warned that should they deviate from this and begin compensating with other areas of their body, they would be stopped and measurements would be taken up to this point. The use of the videotape to review the subjects' technique and movement patterns was very helpful for this. Subjects were again reminded that at any time if they felt that they had to stop the test due to pain or any other reason, they could do so. (No subject had to cease the test prior to completion.)

A 30 second practice session was allowed prior to beginning the tests, followed by a 90 second rest period.

E-5. FST-3: Overhead Throw Test (OTT)

To perform the OTT, subjects were positioned in standing with their feet in a step stance position (opposite leg in front). They held the softball, with the hand of the arm being tested, and the free end of the tube, which was attached to the softball, was secured in a door frame. (see Figure III-7) The subject's arm was then positioned in 90 degrees of abduction and 90 degrees of external rotation with the elbow flexed to 90 degrees. From this position, subjects were instructed to horizontally extend and/or externally rotate their arm to their normal, maximum joint position, in other words, to what felt like their normal wind-up position in a throwing motion. This joint position was recorded.



Figure III-7: Subject Performing Overhead Throw Test

The individualized starting position in the OTT was used in an effort to better represent each subjects' normal shoulder ROM and throwing technique. This was felt to be an extremely important step in this test as it has been well documented that the position of greatest apprehension and instability for individuals with AASI is abduction, horizontal extension and external rotation (DiGiovine et al, 1992; Andrews and Wilk, 1994; Fleisig et al, 1994). Although this is true, one must be careful to ensure that the amount of abduction, horizontal extension and external rotation is specific to that particular individual. An excellent example is the baseball pitcher who, as a result of his sport, develops an external rotation of his pitching arm in the range of 150-180 degrees. In order to accurately test this individual using the OTT, the starting position would have to incorporate this amount of external rotation.

Once the subject was in the starting position, he/she was positioned at a distance away from the attached end of the tube that made the tube "just taut". This was defined as the point where the tube went from being under no tension to just under tension. This tension was checked, by the author, by ensuring that the tube did not have any "sags" and was held at a point that just made it into a straight line from its attachment at the door to the subject's hand. This helped to ensure consistency of the amount of tension/resistance used for the activity between subjects.

The test consisted of the subject doing a throwing motion from his/her start position (described previously), along an arc of motion towards a point in front of his/her body that placed the shoulder in 45 degrees of horizontal cross flexion, 75 degrees of flexion, slight elbow flexion and about 45 degrees of wrist extension. Subjects were instructed that they had to aim the softball to the fixed point, determined by the subject's end position, and they must move their arm through the entire ROM that was set for them. The fixed point

consisted of a pole which could be easily moved to accommodate each subject's specific "end point" position of the throw motion. A 20 second time frame was used and subjects were instructed to perform as many of the throwing motions as they could within this time period. They were advised that proper technique during the test was important and any throw that was not completed through the full, set ROM, or was done through a compensatory movement such as excessive trunk rotation, would not be counted. As in the other FSTs, the use of the videotape was very helpful in reviewing subjects' performance.

Subjects were reminded that if necessary, due to pain or any other reason, they could cease the test at any time. Prior to beginning the test, 30 seconds was allocated for a practice session and as in the previous tests, this was followed by a 90 second recovery period before beginning the actual test.

F. Statistical Analysis

F-1. Subjects Characteristics

Descriptive statistics and frequency analyses were performed on all of the subject demographic information that was collected in this study to determine if any characteristic pattern of either of the two study groups existed. Unpaired t-tests were calculated on the variables age, weight and height to determine if any significant difference existed between the two study groups. (level of significance = 0.01)

F-2. SST and VAS

Descriptive statistics and frequency analyses were computed for the results of the SST and the VAS results to determine if any difference or pattern of difference occurred in and between the two study groups. As well, unpaired t-tests (significance level of 0.01) were performed to see whether the means of each study group differed, indicating that subjects with AASI differed in their subjective rating of function and/or their perception of pain and instability while performing the functional tests.

F-3. FSTs

For all of the FSTs, descriptive statistics, frequency analyses and unpaired t-tests were run to test the hypotheses that subjects in the control group would produce higher scores than the experimental group on all of the FTSs at a level of 0.01 significance.

In all cases, the level of significance (0.01) was chosen to be conservative and minimize the risk of Type I errors occurring from utilizing repeated t-tests in this statistical analysis.

F-4. Correlation Tests

The Pearson Product Moment Correlation tests were used to test the hypotheses that the results between (1) the FSTs and the SST and (2) the FSTs and the VASs would correlate satisfactorily (0.40). At a 0.01 level of significance, the critical value of the correlation (r_{crit}) required was 0.40.

CHAPTER IV

RESULTS

The present study examined the results of subjects with atraumatic anterior shoulder instability, (experimental subjects) and control subjects in performing three objective functional shoulder tests (FSTs): the Shoulder Rotation Test (SRT), the Light Board Test (LBT), and the Overhead Throw Test (OTT). Additional measures were obtained on each subject from a subjective shoulder rating score (Simple Shoulder Test,[SST]) and two visual analogue scales'(VAS) representing pain and sense of instability.

A. Subjects Characteristics

Forty subjects were utilized in this study; twenty in the experimental group (subjects with AASI) and twenty in the control group. The demographics for each subject are listed in Table IV-1. Tables IV-2 and IV-3 present the statistical analysis and frequency distribution of this data.

Table IV-1
Subject Demographics Collected

SUBJECT CHARACTERISTIC	CATEGORY
Age	x: range
Sex	male/female
Weight (kg)	x: range
Height (cm)	x: range
Activity Level	competitive/recreational/weekend/sedentary
Occupation	student/business/laborer/engineer/healthcare
Hand Dominance	right/left
Shoulder Tested	right/left

Table IV-2
Descriptive Statistics for: Age, Weight (kg), Height (cm)

	Age, T	Age, C	Age, E	Wt., T	Wt., C	Wt., E	Ht., T	Ht., C	Ht., E
Mean	24.5	26.2	22.8	71.8	69.8	73.8	175.6	173.5	177.7
SD	4.8	4.6	4.6	10.8	10.5	11.0	7.8	8.5	6.5
SE	0.8	1.0	1.0	1.7	2.4	2.5	1.2	1.9	1.5
Minimum	16	20	16	51	57	51	159	159	163
Maximum	35	35	32	100	93	100	191	189	191

T=total group, C=control group, E=experimental group

Table IV-3: Frequency Distribution of:
Sex, Activity Level, Occupation, Hand Dominance, Shoulder Tested

Characteristic	Total Count	Control Count	Experiment Count
Sex	40	20	20
Male	29	13	16
Female	11	7	4
Activity level	40	20	20
Competitive	12	4	8
Recreational	23	14	9
Weekend	4	1	0
Sedentary	1	1	0
Occupation	40	20	20
Student	26	13	13
Business/Office	7	4	3
Engineer	2	1	1
Physiotherapist	2	2	0
Laborer	3	0	3
Hand Dominance	40	20	20
Right	37	18	19
Left	3	2	1
Shoulder Tested	40	20	20
Right	31	18	13
Left	9	2	7

Unpaired t-tests were computed on the continuous variables - age, weight, and height to determine if any significant differences existed between the two study groups relative to these demographics. These results are listed in Table IV-4. As can be seen in this table, differences were found between the average age of the two groups as well as the average height and weight. The age guideline set by the study's inclusion criteria was 16-35 and although all of the study subjects fell within these set ages, the average age of each study group differed with the experimental group generating a lower average age of 22.8 years, compared to the control group who averaged 26.2 years of age. This difference, although statistically significant, was not felt to have influenced this study's results for two major reasons. Firstly, both groups produced average ages well within the study's age criteria.

Secondly, it was the experimental group that consisted of a younger population therefore if an advantage was to be gained from this age difference it would have more likely occurred in this group, not the older, control group. As will be discussed later, this phenomena did not occur and in fact, despite this lower age, the experimental group generated results on the function tests considerably lower than those of the control group. The difference noted between the weight and height of the two groups utilized in this experiment, was not felt to harm or influence the results of this study. Nothing inherent to any of the testing performed in this study, placed a subject at an advantage if he/she was at a particular weight and/or height.

Table IV-4
Unpaired T-tests for Age, Weight (kg), Height (cm)

	Mean Difference	DF	P-Value
Age: Control, Experimental	3.350	38	0.0261
Weight: Control, Experimental	4.000	38	0.2470
Height: Control, Experimental	4.250	38	0.0841

B. Simple Shoulder Test (SST)

Prior to performing the FSTs, subjects were asked to fill out the SST consisting of 12 questions related to function. A score of 12 indicated that the subject answered "yes" to all of the questions which according to this particular test, implied normal shoulder

functioning. A score of less than 12 indicated that the subject answered "no" to 1 or more of the questions, meaning that he/she was unable to perform a particular functional task.

As can be seen in Table IV-5, all of the control subjects scored 12/12 producing a mean of 12. The SST results of the experimental group demonstrated a range from 8/12 to 12/12 with a resultant mean of 10.25. Of particular interest is the frequency distribution of the SST questions to which the experimental group replied "no". Table IV-6 illustrates this distribution and Table IV-7 presents the corresponding question.

Table IV-5
SST Descriptive Statistics

	SST Score, Total	SST Score, Control	SST Score, Experimental
Mean	11.125	12.000	10.250
Std. Dev.	1.202	0	1.164
Std. Error	0.190	0	0.260
Minimum	8	12	8
Maximum	12	12	12

Table IV-6
Frequency Distribution of "No" Replies

Number of SST Question	Number of "no" replies
2	14
10	8
4	4
7	3
3	2
8	2
12	2
11	1

Table IV-7
SST Questions From Table IV-6

Number of SST Question	Question
2	Does your shoulder allow you to sleep comfortably?
10	Do you think you can toss a softball over-hand twenty yards with the affected extremity?
4	Can you place your hand behind your head with the elbow straight out to the side?
7	Can you lift 8 pounds (a full gallon container) to the level of your shoulder without bending your elbow?
3	Can you reach the small of your back to tuck in your shirt with your hand?
8	Can you carry twenty pounds at your side with the affected extremity?
12	Would your shoulder allow you to work full-time at your regular job?
11	Can you wash the back of your opposite shoulder with the affected extremity?

Statistical difference between the SST score means of the two groups was tested using the unpaired t-test and results are presented in Table IV-8. As can be seen, the difference between the two means was in fact highly significant.

Table IV-8
Unpaired T-test for SST Score

	Mean Difference	DF	P-Value
Control, Experimental	1.750	38	<0.0001

Correlation testing was also computed between the subjects' SST score and the results of their functional shoulder tests (FSTs) and these findings will be presented under section E within this chapter.

C. Functional Shoulder Tests (FSTs)

C-1. Shoulder Rotation Test (SRT)

The SRT consisted of a repetitive internal - external rotation motion with the GH joint positioned at 90 degrees of abduction. Four individual tests were performed, represented in the data results as: Speed 1, Speed 2, Speed 3, and 20 seconds. For the first three tests, subjects were instructed to perform the rotation motion at a specific speed which was consistently set by the investigator for each subject. A total of thirty repetitions was attempted by all of the subjects and the score recorded represents the number of successful rotations the subject was able to complete. For the 20 second test, subjects were instructed to perform as many shoulder rotation motions as they could in the 20 second time frame and the number successfully completed was recorded.

The descriptive statistics of the SRT results are presented in Tables IV-9 to IV-12. One can see from these tables that the two study groups had very little difference in their average number of successful rotation repetitions (out of a maximum of 30) at Speed 1. However, as the speed increased in Speed 2 and even more so in Speed 3, the two study groups began to show differences in their results. The greatest difference was seen during the 20 second test which produced a mean difference of 7 (shoulder rotations).

Table IV-9
Descriptive Statistics for SRT: Speed 1

	Speed 1, Total	Speed 1, Control	Speed 1, Experimental
Mean	29.525	29.900	29.150
Std. Dev.	1.585	0.447	2.159
Std. Error	0.251	0.100	0.483
Minimum	21	28	21
Maximum	30	30	30

Table IV-10
Descriptive Statistics for SRT: Speed 2

	Speed 2, Total	Speed 2, Control	Speed 2, Experimental
Mean	28.550	29.650	27.450
Std. Dev.	2.407	0.875	2.929
Std. Error	0.381	0.196	0.655
Minimum	19	27	19
Maximum	30	30	30

Table IV-11
Descriptive Statistics for SRT: Speed 3

	Speed 3, Total	Speed 3, Control	Speed 3, Experimental
Mean	27.550	29.300	25.800
Std. Dev.	3.289	1.129	3.806
Std. Error	0.520	0.252	0.851
Minimum	16	26	16
Maximum	30	30	30

Table IV-12
Descriptive Statistics for SRT: 20 seconds

	20 Seconds, Total	20 Seconds, Control	20 Seconds, Experimental
Mean	34.000	37.500	30.500
Std. Dev.	5.931	5.052	4.571
Std. Error	0.938	1.130	1.022
Minimum	22	30	22
Maximum	48	48	40

Figures IV-1 to Figure IV-4 illustrate the frequency distribution of the SRT results. It can be seen that as the test became more challenging (Speed 3 and the 20 second test), the distribution of the results became more diverse in both the exercise *and* the control group perhaps demonstrating a more normal distribution range of functional ability.

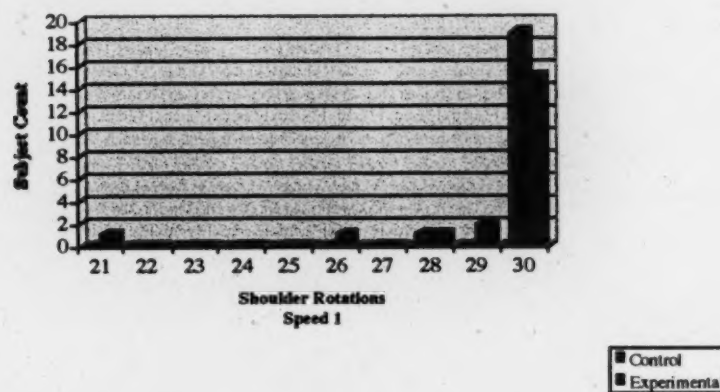


Figure IV-1: Frequency Distribution of SRT: Speed 1

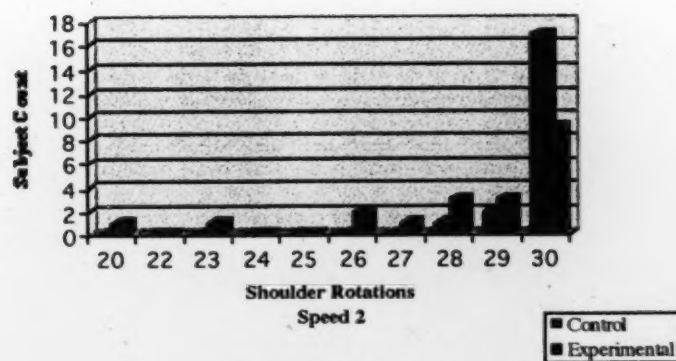


Figure IV-2: Frequency Distribution of SRT: Speed 2

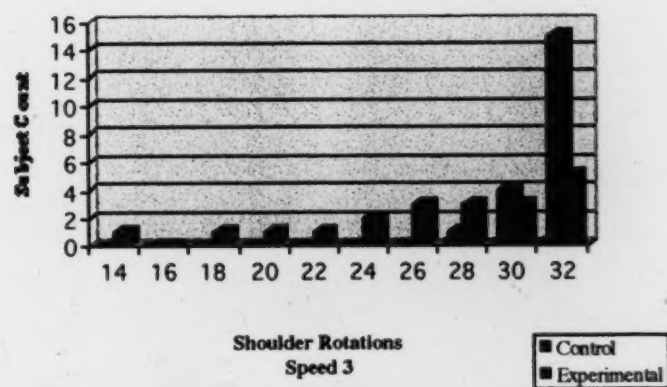


Figure IV-3: Frequency Distribution of SRT: Speed 3

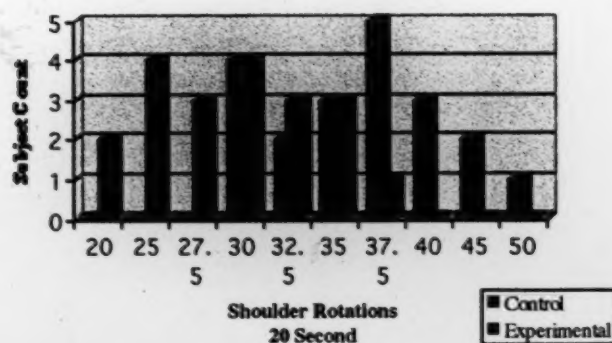


Figure IV-4: Frequency Distribution of SRT: 20 Second

Unpaired t-tests were calculated for each of the four FSTs and these results are shown in Table IV-13. For Speed 1, a mean difference of only 0.750 at 38 degrees of freedom, produced a P-value which states that there is a 14% chance that this observed difference occurred by chance and therefore is not considered statistically significant. Speed 2 produced a P-value which states that there is only a 0.26% chance of the difference between the means occurring by chance, and Speed 3 and the 20 second test continued to show greater significance as well. This certainly seems to suggest that at the more challenging (faster) speeds, subjects with AASI are unable to perform this particular functional activity as well as subjects with normal shoulders.

Table IV-13
Unpaired T-tests for SRTs

	Mean Difference	DF	P-Value
Speed 1: C, E	0.75	38	0.1364
Speed 2: C, E	2.20	38	0.0026
Speed 3: C, E	3.50	38	0.0003
20 Seconds: C, E	7.00	38	<0.0001

C = control group, E = experimental group

C-2. Light Board Test (LBT)

The LBT involved an eye-to-arm neuromuscular coordination test in which subjects touched as many of the lights that were sequentially illuminated in a predetermined pattern. Three individual tests were performed, represented in the data results as: LBT-1, LBT-2, and LBT-3. Each test lasted 30 seconds and the sequence of the lights was pre-set and identical for each subject. The tests differed in the speed at which the lights came on and off. For LBT-1 it was every 2.0 seconds, LBT-2 was every 1.0 second and LBT-3 was every 0.75 second. The light board contained a computerized counting system which recorded the number of successful touches for each set sequence. This was the number that was recorded as the LBT data.

The descriptive statistics for LBT-1, LBT-2, and LBT-3 are listed in Table IV-14 to IV-16 and the frequency distributions for the corresponding tests are shown in Figures IV-5 to IV-7. As can be seen in the following figures and tables, both the control and the

experimental groups demonstrated very wide ranges of results. This phenomenon will be discussed further in the next chapter.

Table IV-14
Descriptive Statistics for LBT-1

	LBT-1, Total	LBT-2, Control	LBT-3, Experimental
Mean	20.950	20.950	20.950
Std. Dev.	5.286	6.048	4.559
Std. Error	0.836	1.352	1.019
Minimum	10	10	12
Maximum	32	30	32

Table IV-15
Descriptive Statistics for LBT-2

	LBT-2, Total	LBT-2, Control	LBT-2, Experimental
Mean	20.275	20.450	20.100
Std. Dev.	5.325	5.114	5.656
Std. Error	0.842	1.144	1.265
Minimum	9	13	9
Maximum	32	32	30

Table IV-16
Descriptive Statistics for LBT-3

	LBT-3, Total	LBT-3, Control	LBT-3, Experimental
Mean	14.100	15.200	13.000
Std. Dev.	5.647	5.268	5.929
Std. Error	0.893	1.178	1.326
Minimum	4	6	4
Maximum	29	25	29

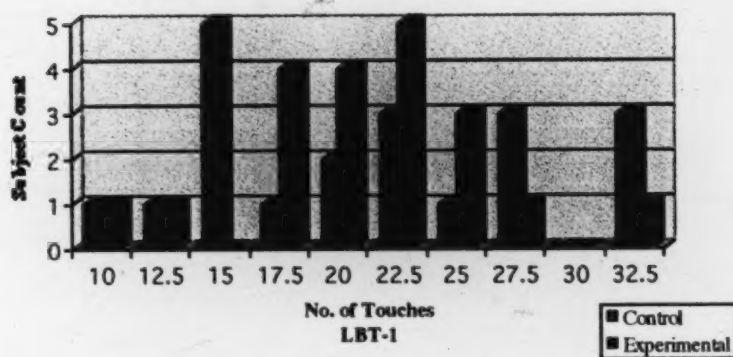


Figure IV-5: Frequency Distribution of LBT-1

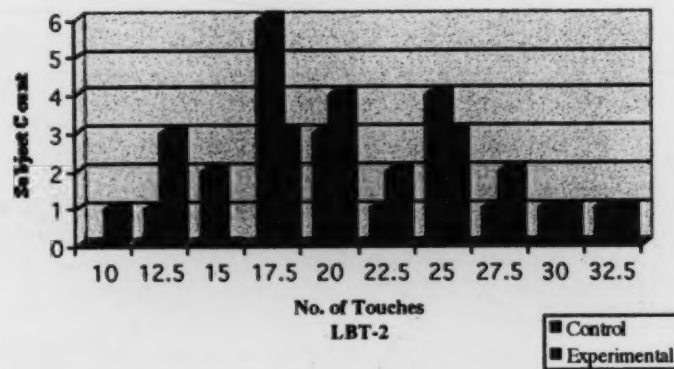


Figure IV-6: Frequency Distribution of LBT-2

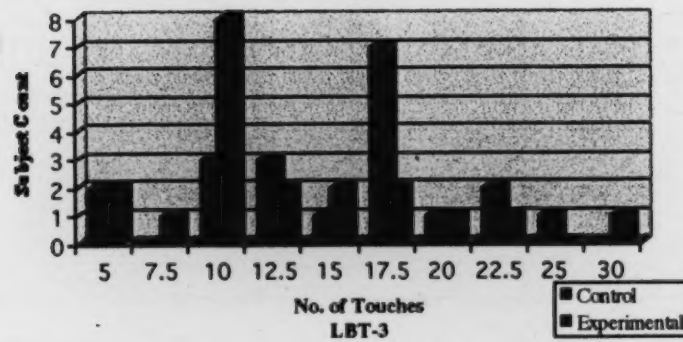


Figure IV-7: Frequency Distribution of LBT-3

As in the SRT, unpaired t-tests were used to determine if the difference between the means was statistically significant. For LBT-1, both study groups produced the same mean of

20.95, indicating no significant difference. (see Table IV-17) LBT-2 was also found not to be statistically significant, as its P-value indicates that there was a 84% chance that the difference that occurred between the means was due to chance. A P-value of 0.2224 was calculated for LBT-3 which, although better than the first and second tests, still did not indicate a significant difference between the two means. The directional trend towards significance as the speed of the test increased is interesting and leads one to believe that if the test speeds had been further increased, a significant difference could possibly have been detected between the two study groups.

Table IV-17
Unpaired T-test for LBTs

	Mean Difference	DF	P-Value
LBT-1: C, E	0.000	38	n/a
LBT-2: C, E	0.350	38	0.8385
LBT-3: C, E	2.200	38	0.2224

C = control group, E = experimental group

C-3. Overhead Throw Test (OTT)

The OTT consisted of a timed, simulated overhead throwing motion. One test was performed per subject yielding one recorded value. Subjects were instructed to complete as

many "throws" in a 20 second timed period and the number of successful throws was recorded.

Descriptive statistics are listed in Table IV-18 and Figure IV-8 illustrate the frequency distribution of the results.

Table IV-18
Descriptive Statistics for OTT

	No. of Throws, Total	No. of Throws, Control	No. of Throws, Experimental
Mean	17.250	19.800	14.700
Std. Dev.	5.103	4.299	4.612
Std. Error	0.807	0.961	1.031
Minimum	4	11	4
Maximum	28	28	23

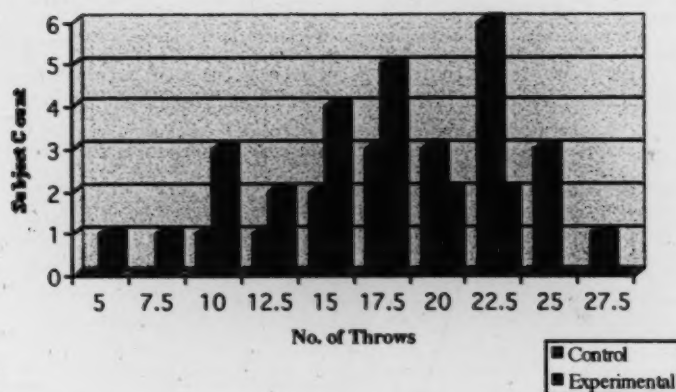


Figure IV-8: Frequency Distribution of OTT

Unpaired t-test results, shown in Table IV-19, demonstrate a highly significant difference in comparing the means of the control and the experimental group.

Table IV-19
Unpaired T-test for OTT

	Mean Difference	DF	P-Value
C, E groups	5.100	38	0.0009

C = control, E = experiment

D. Visual Analogue Scale (VASs)

Following each of the three FSTs, subjects were asked to rate the amount of pain and feeling of instability they had during the test. Two VASs were therefore used per FST, one representing pain and one representing instability, yielding a total of six values per subject.

The descriptive statistics of these results are listed in Table IV-20, IV-21, IV-22, IV-23, and IV-24, IV-25.

Table IV-20
Descriptive Statistics for VAS-pain (mm): SRT

	VAS-pain, Total	VAS-pain, Control	VAS-pain, Experimental
Mean	18.525	4.575	32.475
Std. Dev.	23.031	7.443	24.974
Std. Error	3.642	1.664	5.584
Minimum	0.000	0.000	0.000
Maximum	81.500	23.000	81.500

Table IV-21
Descriptive Statistics for VAS-instability (mm): SRT

	VAS-inst, Total	VAS-inst, Control	VAS-inst, Experimental
Mean	18.775	1.075	36.475
Std. Dev.	25.095	2.682	25.019
Std. Error	3.968	0.600	5.594
Minimum	0.000	0.000	0.000
Maximum	75.000	9.500	75.000

Table IV-22
Descriptive Statistics for VAS-pain (mm): LBT

	VAS-pain, Total	VAS-pain, Control	VAS-pain, Experimental
Mean	9.025	0.125	17.925
Std. Dev.	17.119	0.559	20.844
Std. Error	2.707	0.125	4.661
Minimum	0.000	0.000	0.000
Maximum	67.500	2.500	67.500

Table IV-23
Descriptive Statistics for VAS-instability (mm): LBT

	VAS-inst, Total	VAS-inst, Control	VAS-inst, Experimental
Mean	10.012	0.000	20.025
Std. Dev.	17.891	0.000	21.118
Std. Error	2.829	0.000	4.722
Minimum	0.000	0.000	0.000
Maximum	69.000	0.000	69.000

Table IV-24
Descriptive Statistics for VAS-pain (mm): OTT

	VAS-pain, Total	VAS-pain, Control	VAS-pain, Experimental
Mean	14.975	3.325	26.625
Std. Dev.	20.486	5.561	23.341
Std. Error	3.239	1.244	5.219
Minimum	0.000	0.000	1.000
Maximum	100.000	18.000	100.000

Table IV-25
Descriptive Statistics for VAS-instability (mm): OTT

	VAS-inst, Total	VAS-inst, Control	VAS-inst, Experimental
Mean	19.875	1.225	38.525
Std. Dev.	26.382	3.168	26.197
Std. Error	4.171	0.708	5.858
Minimum	0.000	0.000	0.000
Maximum	100.000	13.000	100.000

A series of unpaired t-tests were done for each of the VASs to determine if the difference between the means of the control and the experimental group is statistically significant. Tables IV-26 to IV-28, indicate that for each of the FSTs, subjects in the experimental group differed significantly from the control group in their subjective rating of the amount of pain and the sense of shoulder instability they experienced.

Table IV-26
Unpaired T-test for VAS-pain and VAS-instability: SRT

	Mean Difference	DF	P- Value
VAS-pain: C, E group	27.900	38	<0.0001
VAS-inst: C, E group	35.400	38	<0.0001

C = control, E = experimental

Table IV-27
Unpaired T-test for VAS-pain and VAS-instability: LBT

	Mean Difference	DF	P-Value
VAS-pain: C, E group	17.800	38	0.0005
VAS-inst: C, E group	20.025	38	0.0001

C = control, E = experimental

Table IV-28
Unpaired T-test for VAS-pain and VAS-instability: OTT

	Mean Difference	DF	P-Value
VAS-pain: C, E group	23.300	38	0.0001
VAS-inst: C, E group	37.300	38	<0.0001

C = control, E = experimental

E. Correlation Test Results

The main objective of this study was to test the performance of control subjects and experimental subjects (those with AASI) on the three FSTs. The second objective was to compare the measures obtained from the FSTs with the measures obtained from (a) the Simple Shoulder Test and (b) the VASs on pain and instability to determine if any relationship or correlation exists.

E-1. Correlation Between FSTs and SST

SRT and SST

Correlation test results between the SRT and the SST are presented in Table IV-29.

Table IV-29
Correlation Results for the SST and the SRT

	Speed 1	Speed 2	Speed 3	20 Seconds
SST Score: C group	N/A	N/A	N/A	N/A
SST Score: E group	-0.079	0.459	0.143	0.401

C = control, E = experimental

LBT and SST

Correlation test results between the LBT and the SST are presented in Table IV-30.

Table IV-30
Correlation Results for the SST and the LBT

	LBT-1	LBT-2	LBT-3
SST Score: C group	N/A	N/A	N/A
SST Score: E group	0.250	0.396	-0.076

C = control, E = experimental

OTT and SST

Correlation test results between the OTT and the SST are presented in Table IV-31.

Table IV-31
Correlation Results for the SST and the OTT

	No. of Throws/OTT
SST Score: C group	N/A
SST Score: E group	-0.162

C = control, E = experimental

From the preceding correlation test results, one can see that there were few significant relationships identified between the measures of the FSTs and the results of the SST. No variance was detected amongst the SST results of the control group as all 20 subjects

scored 12 out of a possible 12. Therefore the correlation value between the SST results and the results of the FSTs is not applicable (N/A). Further discussion of these results can be found in the next chapter.

E-2. Correlation Between FSTs and VASs

SRT and VAS

Correlation test results between the SRTs and the VASs for pain and sense of instability are listed in Table IV-32.

Table IV-32
Correlation Results from the VAS-pain and VAS-instability and SRT

	Speed 1	Speed 2	Speed 3	20 Seconds
VAS-pain: C group	-0.425	-0.178	-0.194	-0.475
VAS-pain: E group	-0.002	-0.113	0.044	0.246
VAS-inst: C group	0.094	0.169	0.262	-0.020
VAS-inst: E group	0.160	-0.171	-0.109	-0.151

C = control, E = experimental

LBT and VAS

Correlation test results between the LBTs and the VASs for pain and sense of instability are listed in Table IV-33. The correlation value between the control subjects' results on the three LBTs and their subjective rating of instability was not applicable (N/A) because all of the 20 subjects rated their instability during the test as 0.

Table IV-33
Correlation Results from the VAS-pain and VAS-instability and LBT

	LBT-1	LBT-2	LBT-3
VAS-pain: C group	-0.115	0.209	0.438
VAS-pain: E group	-0.261	-0.573	-0.156
VAS-inst: C group	N/A	N/A	N/A
VAS-inst: E group	-0.272	-0.511	-0.156

C = control, E = experimental

OTT and VAS

Correlation test results between the OTT and the VASs for pain and sense of instability are listed in Table IV-34.

Similar to the correlation test results found between the FSTs and the SST, correlations calculated between the FST measures and the VAS results were not strong. Further discussion of these results may be found in the following chapter.

Table IV-34
Correlation Results from the VAS-pain and VAS-instability and OTT

	No. of Throws/OTT
VAS-pain: C group	-0.167
VAS-pain: E group	-0.219
VAS-inst: C group	0.206
VAS-inst: E group	-0.003

C = control, E = experimental

CHAPTER 5

DISCUSSION

Objective functional testing of the unstable shoulder is a relatively new, unstudied area in orthopaedics and sports medicine. Similar types of performance tests have been developed and tested in other joints such as the knee, wrist and hand, and their use has provided the clinician with a valuable measurement tool of an individual's functional ability and/or disability. In shoulder instability syndromes, such as AASI, where individuals present with significant losses of function as a result of apprehension during overhead activity, it would seem to be very beneficial to supplement the typical clinical tests that are presently done, with some form of objective test or tests that measure an individual's shoulder function.

The purpose of this study was to utilize three objective functional shoulder tests (FSTs) and compare the results from these tests on subjects with AASI and subjects with normal shoulders. The FST results of both groups of subjects were also compared to two subjective rating scores, the Simple Shoulder Test (SST) and visual analogue scales (VAS) for pain and sense of instability to determine if any correlation existed.

A. Functional Shoulder Tests (FSTs)

The purpose of the three FSTs, that were utilized in this study, was to determine and quantitatively measure the ability/inability of an individual to perform designated functional tasks. These functional tasks were designed to reproduce functional joint positions, muscle

performance, and neuromuscular patterns typically used at the GH joint. Two study groups were examined (an experimental group consisting of subjects with AASI and a control group consisting of subjects with normal shoulders), to determine if the FST results differed in the two sample populations.

All of the FSTs, with the exception of one of the individual LBTs, produced higher average scores in the control group. Two of the three FSTs demonstrated highly significant differences between the two study groups. These were the Shoulder Rotation Test (SRT) and the Overhead Throw Test (OTT). The Light Board Test (LBT) failed to produce a difference that was considered statistically significant, however, it did demonstrate a directional trend towards significance with the experimental group generating lower performance scores as the test became more challenging.

A-1. FST-1:Shoulder Rotation Test (SRT)

The SRT consisted of four individual tests represented as: Speed 1, Speed 2, Speed 3, and 20 seconds. Each successive test became more challenging as subjects were required to perform the rotation movement at a faster speed.

At Speed 1 (1 repetition/second), very little difference was seen between the two groups' results. A P-value of 0.1364 was produced meaning there was a 13.6 % chance that the observed difference between the normal and the AASI subjects occurred as a result of chance.

As the speed of rotation at the shoulder increased in Speed 2 (2 repetitions/second) and Speed 3 (4 repetitions/second), greater differences in the two groups' results began to emerge. Both of these individual tests produced significantly different means; Speed 2 at a P-value of 0.0026 and Speed 3 at 0.0003. As expected, as the speed of shoulder rotation required increased from SRT-1 ("Speed 1") to SRT-3 ("Speed 3"), subjects with AASI experienced more difficulty in performing the functional activity and as a result produced lower test scores.

This finding supports similar research in other joint instability syndromes, which has discovered that, as the speed of an activity increases, the demands and stresses placed on the affected joint increase significantly and may lead to apprehension, pain and dysfunction (Bassett et al, 1988; Dines and Levinson, 1995; Kvitne and Jobe, 1995).

The fourth SRT, the 20 second test, differed from the previous three in that subjects were not required to perform the rotation at a set pace but were instead asked to complete as many of the rotation motions as they could in a timed 20 second time frame. The results in both study groups would indicate that this test was the most challenging, as the average number of rotations exceeded those averages generated in the Speed 3 test.

Results from the 20 second test produced the greatest difference in the average number of shoulder rotation motions performed between the two groups. A mean difference of 7 rotations produced a P-value of <0.0001 which essentially meant that there was no chance that the observed difference between the two subject groups occurred as a result of chance. In other words, the difference that was observed was in fact real.

Another phenomena that was observed from the results of the SRTs, was the range of test scores generated by both the study groups examined. At Speed 1, the control subjects all produced scores between 28 and 30 out of a possible 30 repetitions. At Speed 2, this range expanded to 27 to 30 out of 30 and at Speed 3, 26 to 30 out of 30. The 20 second test produced a range from a minimum value of 30 to a maximum of 48 rotations in the control group. This trend would suggest that even amongst subjects with normal shoulders, the SRTs became more challenging at higher speeds and at the extreme speed (the 20 second test), the subjects' varying results likely reflected a normal distribution of functional ability which takes into account factors such as skill level, muscle strength, reaction time, and endurance.

This variability was also demonstrated by the experimental group, with even wider ranges of test results produced (Speed 1: 21 to 30 rotations out of 30; Speed 2: 19 to 30 rotations out of 30; Speed 3: 16 to 30 rotations out of 30; 20 Second: 22 to 40 rotations). This range may also be explained as being representative of a normal distribution of functional ability in this sample population, but also very likely, is influenced by the varying degree of symptoms experienced amongst individuals with AASI.

The overall results that were produced from the SRT were very encouraging. Not only because of the significant difference that was seen between the two populations, but also because of the directional trend that developed.

The SRT was developed utilizing the concepts of specific GH joint position, speed and endurance. Sound research findings and clinical experience has proven that one of the most aggravating joint positions for individuals with AASI is shoulder abduction and external

rotation (Perry , 1983; Bassett et al , 1988; Andrews and Wilk, 1994) which was the exact position that subjects were asked to move into during the SRT, with the added challenge of performing this rotation at relatively fast speeds for a total of 30 repetitions or more. It was expected that as subjects with AASI were required to increase the speed of their rotation, and repeat this movement pattern, they would develop pain and apprehension from being in the unstable position of abduction and external rotation. This was precisely what occurred.

AASI subjects were generally able to maintain the speed and repetition requirement of the tests, but as the tests became more challenging, they began to "miss" the external rotation support on the shoulder rotation board. In other words, they did not abduct and externally rotate their arm to the position required to touch the external rotation support. They could do so however, if the test was performed slower. Another observation, which is not evidenced in the test results, was that the subjects' performance definitely worsened as they progressed through the 30 repetitions to the end of the test. If a subject scored 25 out of a possible 30, it was very likely that the 5 touches that were incomplete occurred towards the end of the test as the subject appeared to become fatigued and possibly more apprehensive. This certainly supports the theory that has suggested that as the dynamic stabilizers of the GH joint fatigue or weaken, the joint becomes more unstable and painful due to secondary impingement (Allegrucci et al, 1994).

A-2. FST-2: Light Board Test (LBT)

The LBT consisted of three separate tests: LBT-1, LBT-2, and LBT-3. The tests differed in the speed at which the lights flashed on and off on the light board.

The first test (LBT-1), produced identical means for subjects in the control group and the experimental group. The range and variability of the test results generated from the two groups were also similar with the control group ranging from 10 to 30 lights touched and the experimental group from 12 to 32. No significant difference was detected from the results of this test, in fact the highest recorded result (32 light touches), was generated by one of the AASI subjects.

LBT-2, also, produced results that were not statistically significant when comparing the two study groups, although the control group did produce a slightly higher average number of lights successfully touched. A P-value of 0.8385 suggested that this small, observed difference had a very high likelihood of occurring as a result of chance. The range in the individual test results once again showed a great deal of variability, producing values in the control group of 13 to 32, and 9 to 30 in the experimental group.

The most challenging of the LBTs, LBT-3, also failed to demonstrate a statistically significant difference between normal and AASI subjects. A greater difference was observed between the two means, however the P-value calculated from this difference was 0.2224, much greater than the 0.01 level of significance set by this study.

As was noted in the previous two LBTs, the range of test results in LBT-3 was also remarkably large in both study groups. In the control group, this range was a minimum result of 6, maximum of 25, and in the experimental group, a minimum of 4 and maximum of 29. Interestingly, the maximum number of lights successfully touched in the LBT-3 sequence, was obtained by a subject in the experiment (AASI) group.

The lack of significance demonstrated with the LBT may have several explanations. First of all, the test itself was developed in an effort to examine neuromuscular coordination. Although related research has suggested that this important component of normal activity becomes deficient in patients with chronic joint instability syndromes, to date no study has discovered a functional manner by which it can be measured. Smith and Brunolli (1989) and Lephart and colleagues (1993) both demonstrated deficits in proprioception and neuromuscular coordination in patients who had sustained acute GH joint dislocations and unilateral instability syndromes respectively. However, both experiments utilized an isokinetic dynamometer (ie. Cybex) for their study, and subjects were asked to reproduce shoulder joint positions and react to angle changes that were set by the machine. Certainly any information acquired in this area of study is valuable, however, these studies as well as others are being criticized because they are not representative of normal, functional activities and do not correlate well with functional outcomes. Clinical experience suggests that a football player returning to activity following an anterior cruciate ligament injury may be more suitably tested with a shuttle run or a hop test than a Cybex isokinetic knee flexion and extension test, as the information gained from the more functionally related tests provides the individual, and the clinician, with information about functional knee joint stability, muscle performance, confidence, speed reaction time and pain during activity, as opposed to just strength which would be the measure obtained from the Cybex test. Unfortunately, functional tests can sometimes be more difficult to use than more

conventional measurement tools and it is difficult when trying to reproduce a functional activity, to control for things such as compensatory joint and muscle activity, previous learning patterns and experiences, and sensory acuteness. In the football player example, two subjects' results may differ not as a result of varying levels of ACL instability, but possibly because one subject has a stronger upper body to thrust himself forward in the hop test, or perhaps he previously trained as a sprinter and is inherently a faster runner. In the LBT, some of these extraneous factors may have also contributed to the results that subjects obtained.

Unlike the other two FSTs, it was much more difficult to control possible contributory muscles and joints from assisting in this LBT activity. All subjects were stabilized against the platform upon which the light board rested, and were manually stabilized at the sternum and the upper thoracic spine. However, upon review of the subjects' performance on the videotape, it appeared that, subjects were successful in using their trunk and/or upper body to facilitate the shoulder motion needed to do this particular function test. This compensatory movement was more evident during this test than any of the other FSTs.

The second question which must be addressed is what precisely the test was measuring. Originally the test was developed as being representative of neuromuscular coordination and position sense at the GH joint. However, having observed subjects in both groups perform the test, and carefully reviewing their movement patterns on the videotape, it appeared as though the test could just as easily have been measuring the subject's visual acuity ie. peripheral vision, which in reality the light board was originally designed to test and improve.

The final consideration, which might help explain the failure of this test to show significant differences between the two groups, is the concept of previous learning and training patterns. A perfect example occurred in LBT-3. This test was the most challenging of the three, as the speed at which the lights flashed on and off was every 0.75 seconds. The maximum number of lights touched during this test was 29 and this was obtained by a subject with AASI. What is interesting about this finding, other than it occurred in the experimental group, is that the individual who achieved this test result is a national level volleyball player. This subject's level of training, which involves a great deal of fast reaction exercises and quick joint and muscle performances, very likely put her at an advantage in doing this FST.

In summary, the LBT, as it was used in this particular study, did not generate significant differences in the results of the two study groups. Several contributing factors have been presented as possible explanations for this phenomena. It did however show a directional trend towards significance that may indicate that at faster test speeds, subjects with AASI would produce results significantly lower than those of normal subjects.

A-3. FST-3: Overhead Throw Test (OTT)

The OTT consisted of a single, 20 second timed test in which subjects performed as many overhead throws as possible. The results generated from this FST were found to be significant at the 0.01 level of significance selected for this study. As in all of the FSTs, subjects in the control group generated the higher scores producing a mean difference of 5.1 and a P-value of 0.0009. This meant that the observed difference between the two study groups had a 0.09% chance of occurring as a result of chance.

The range of scores in the control group went from 11 throws to 28, and in the experimental group, 4 to 23 throws. Once again, both groups demonstrated considerable variability in their ability to perform the functional task.

The utilization of some type of functional test that simulated a throwing motion seemed logical considering the epidemiology of the instability in question. AASI has been repeatedly reported as occurring primarily in athletes and/or individuals involved in overhead activities (Hill, 1983; McLeod and Andrews, 1986; Kvitne et al, 1995; Pettrone, 1995). The two sports that have the highest incidence of AASI are baseball and swimming and in both instances, it is in the overhead, externally rotated and/or extended GH joint position that the instability occurs (Richardson et al, 1980; Abrams, 1991; Andrews and Wilk, 1994). As well, throwing is such a common, functional activity that is performed by so many people, that it was not believed to place any individual at an advantage in terms of skill or learning patterns. Another advantage to this particular FST, was its ease of use as a testing tool and the simplicity of the equipment.

The functional components that were considered in establishing the OTT were specific GH joint position, muscle and joint endurance and speed. It is very likely not a coincidence that these similar factors were considered in the development of the SRT, the other FST found to produce a significant difference.

It was expected, and found to be correct, that subjects with AASI would perform fewer throws than the control group primarily because of the sense of instability and pain that would be produced from this activity.

A-4. Summary of Functional Shoulder Test results

The SRT and the OTT were found to produce very significantly different test results when comparing subjects with normal shoulders to subjects with AASI. The LBT failed to demonstrate this same significant difference however it did show a trend towards this, had the test been made more challenging. In most of the FSTs, both study groups generated results which were quite varied, possibly representing a normal range of ability in performing a functional activity.

In conclusion, the following research hypotheses were proven correct:

- (1) Subjects with AASI (experimental subjects) were not able to complete as many of the repeated shoulder motions as the control group.
- (2) Subjects with AASI (experimental subjects) were not able to complete as many of the overhead throws in the 20 second time period as the control subjects.

The results generated from the second FST, the LBT, resulted in the rejection of the following research hypotheses:

- (1) Subjects with AASI (experimental subjects) were not able to accurately touch as many lights on the light board, as the control subjects.

B. Simple Shoulder Test (SST)

Subjects from both study groups in this study, scored relatively high on the SST. All of the control subjects scored 12 out of 12 while the experimental group produced an average of

10.25 out of 12. The question most commonly answered "no" to in the experimental group was question 2 with 14 of the 20 subjects involved replying in this manner. This question inquires whether the affected shoulder allows one to sleep comfortably. The fact that about 75% of the subjects with AASI, tested in this study, answered that sleep was indeed an aggravating activity, at first appears puzzling. AASI is a condition which is often defined by its etiology of overhead, dynamic activity. Sleeping certainly does not typically fall into this category of activity, however, it is entirely possible as evidenced in this study, that subjects may be sleeping in a position which places their arm in an abducted and externally rotated joint position.

The question that produced the second highest number of "no's", was number 10, which asked the subject if they thought they could toss a softball overhand twenty yards (18 meters) with the affected extremity. This result was not surprising, as this is the type of mechanism that generally will produce symptoms of pain and instability in AASI. It is also the specific joint position that was utilized in two of the three FSTs.

A difference was detected between the two study groups' results in the SST. A P-value of <0.0001 suggested a very significant difference. Although statistically this is quite impressive, a few questions regarding the results of the SST arise. First of all, an average score for the experimental group of 10.25 out of 12 appears rather high. According to Lippitt and his colleagues, this reflects a fairly high level of functional ability. Certainly some of the AASI subjects examined in this study, might disagree with that classification. One of the major concerns in using shoulder subjective rating scores for function is how well they actually represent "function". The available literature on measuring function at the shoulder has demonstrated that no clear definition of what shoulder function is exists, however most authors believe that function can be represented by the ability to perform

basic activities of daily life (ADL). In populations such as athletes, disabled individuals and the elderly, these "activities of daily life" are not always indicative of what their "function" is. In this particular study, it is believed that because AASI is a condition that is not typically aggravated with ADL, but more as a result of overhead work and/or sporting activities, the typical subjective rating scores utilized today may not distinguish this functional loss. This may explain what occurred with the experimental group in this study.

The SST was chosen for use in this study, because the content of the questions included tasks related to work, rest and sporting activities. It was developed as a shoulder function questionnaire that could be utilized by a large, diverse population of shoulder patients and as a result its questions are general and not specific to the complaints of one type of shoulder syndrome. Based on the results generated from the subjects with AASI tested in this study, one might conclude that although the SST attempts to measure shoulder function in a variety of different tasks, it may not be an appropriate subjective rating score to use on individuals with this type of instability syndrome.

The use of the SST in this study was also in an effort to determine if any correlation existed between its results and those of the FSTs. These findings will be discussed under section "D. Correlation Results".

C. Visual Analogue Scales (VASs)

Two separate VASs were utilized in this study to measure the subjects' subjective rating of the amount of pain and sense of instability they experienced during the FSTs. It was believed that pain and instability would be the primary symptoms that subjects with AASI

would experience during the FSTs resulting in lower overall performance. It was also theorized that a moderately strong correlation would exist between a subject's performance and his/her rating of pain and instability. Specifically, the lower the FST result, the higher the rating of pain and instability. Correlation findings will be discussed in the next section.

In FST-1, the SRT, subjects' in the experimental group produced significantly different VAS results when compared to subjects in the control group. The rating of pain generated a mean difference of 27.9, producing a P-value of <0.0001 . This result meant that there was less than a 0.01% likelihood that the observed difference between the two groups occurred due to chance. This large difference was also seen in the subjects' rating of instability with a mean difference of 35.4 being measured and a resultant P-value of once again, <0.0001 . These results certainly support previous findings which have identified the two major complaints of subjects with AASI as pain and a feeling of instability when they are placed in a stressful GH joint position and/or required to perform an activity quickly for long periods of time in an unstable position.

The LBT, which was previously found to not show significantly different results in the two study groups, did demonstrate very significant differences in the perception of pain and instability that the two subject groups experienced. Pain was rated 17.8 (mm) greater in the experimental group, causing the P-value to be 0.0005, a low enough level to conclude that the difference that occurred between the groups was in fact real. A slightly greater difference in the means was detected with the rating of instability (20.03) resulting in an even lower P value of 0.0001. These findings suggest that in spite of the LBT results not being significantly different, subjects in the experimental group experienced much more of the expected sensations of pain and instability from performing the activity.

The third FST, the OTT, also produced significant differences in the amount of pain and instability that the two study groups reported. A mean difference of 23.3 was calculated from the pain rating, resulting in a 0.0001 P-value and an even greater difference in the average rating of instability (37.3) produced an even smaller P-value of <0.0001 . As in the previously noted FSTs, these findings suggest that the OTT was in fact "stressful" on the GH joint of subjects with AASI, causing rather considerable pain and feelings of instability. In fact, during this third FST, two of the experimental group subjects experienced partial subluxation episodes of their GH joint.

Of additional interest in reviewing the VAS results of both groups, was the finding that subjects with normal shoulders (control group) were not completely without some of the sensations of pain and instability experienced by the experimental group. The rating of pain was greatest amongst this group during the SRT but also evidenced during the OTT. Only minimal reports of pain and instability were noted during the LBT. These results are felt to provide strength to the function tests themselves, as they clearly provide enough of a challenge that even amongst a normal population, a certain amount of "normal" stress is felt at the shoulder.

D. Correlation Results

The second objective of this study was to compare the subjects' results generated from the FSTs with those of the SST and the VASs. It was hypothesized that a correlation would be detected between the FSTs and the SST results and the FSTs and the VAS results. At a significance level of 0.01, the critical correlation value (r -critical) calculated is 0.40. This

means that a correlation of 0.40 or greater is necessary for the result to be considered significant at the level of significance selected for this study. The direction of the correlation was not stated in the research hypothesis, however it is fairly important in the interpretation of the correlation result. It was expected that if a subject performed poorly on the FST (ie. a low score), they would also produce a low score on the SST (indicating greater functional limitation). This low score would produce a positive correlation value. With the FST-VAS tests, it was expected that if a subject produced a low score on a FST, they would rate the amount of pain and instability they experienced during the test quite high. This inverse relationship would result in a negative correlation value.

D-1. Functional Shoulder Test - Simple Shoulder Test

Shoulder Rotation Test (SRT)

In the SRT, correlations were found to range, in the experimental group, from -0.079 to 0.459. The correlation coefficients calculated between the control groups' SST results and their corresponding SRT results, were not applicable as all of the control subjects yielded the same score on the SST (12 of 12). The absence of variability amongst this value makes correlation calculations unfeasible. Significance in the experimental group, at the 0.01 level, was demonstrated at SRT-Speed 2 and SRT-20 Seconds. The positive nature of the correlation indicates that if the subjects' SST score was low, his/her SRT result was also low. This was the relationship that was expected to occur. The poor correlation calculated at Speed 1 may be explained by the fact that subjects performed fairly well at this slow speed, producing the majority of their results between 28 and 30 rotations. What is not clearly understood is the correlation of 0.143 that was found to exist between the SST and SRT-Speed 3, especially considering Speed 2 and 20 Seconds were greater than 0.40 (statistically significant). All of the previous statistical findings relative to the SRT,

demonstrated a systematic trend as the speeds increased and the tests became more challenging. This trend was expected to also occur between these two variables.

Light Board Test (LBT)

The LBT produced one significant correlation with the SST results. This correlation occurred in the experimental group, with the LBT-2. A correlation of 0.396 (0.40) was detected indicating that when the subjects' results from the LBT were low (ie. lower number of successful light touches), their results on the SST score were also low. As in the SRT, an unusual trend was seen in viewing the correlations between these two variables, causing one to question the interpretation of the significance that was detected. In the easiest of the three tests (LBT-1), subjects in the experimental group generated a correlation of 0.250 between their LBT results and their SST scores. As noted above, LBT-2 produced a correlation of 0.396, considered significant for this study. So far this trend is consistent with previous findings. The correlation calculated between the LBT-3 results and the experimental subjects' SST scores however, was found to be -0.076. Not only is this an extremely poor correlation, but the negative description of the value would indicate an inverse relationship of the two variables. In other words, if subjects produced lower test results on the LBT, they would produce higher scores on the SST. This clearly is not what was expected to be found, especially at LBT-3 which was the most difficult of the three tests and the only one to demonstrate a difference between the two group means. One possible explanation for this finding might be that a subject from the experimental group produced the highest value on the LBT-3. This same individual scored 10 out of 12 on the SST (below the average of 10.25). Perhaps this result altered the correlation calculations enough to produce this correlation. As in the SRT, correlation values were found to be not applicable between the control subjects' LBT results and their SST results because the SST scores generated in this study group were all identical.

Overhead Throw Test (OTT)

Results from the OTT, when correlated with the SST scores, produced a value in the experimental group of -0.162. This is a low (statistically insignificant) correlation between the two variables with a direction that suggests that a higher OTT result (number of throws) is correlated with a lower SST score. Similar to the findings in the previously mentioned FSTs, this poor correlation was not expected and the directional relationship suggested between the variables was opposite to what was thought should have occurred. Once again, correlation values between the control groups' SST results and OTT results produced findings that were not applicable due to the lack of variability amongst the SST scores.

In summary, only a few significant correlations were observed between the FST results and the SST in the experimental group. Some explanations for this phenomena have already been offered however one major consideration which must be addressed is the SST itself. Previously, comments were made regarding the appropriateness of this subjective rating score for this study. Although it is superior to other shoulder rating scores in that it attempts to address functions required for work, rest and sport, it still was found to not be highly discriminate for the sample population investigated in this study. An average score, amongst the AASI subjects, of 10.25 out of 12 would indicate a relatively high level of function. The question is, does the SST's definition of "function" accurately represent the AASI subjects' definition of function. Certainly none of the 20 AASI subjects interviewed in this study would have described their level of function as "high" and the FST results and corresponding ratings of pain and sense of instability, definitely suggest the presence of significant functional limitations. This weak representation of "function" from the SST scores may help to understand the low correlation values that were produced, as well as the

unusual trends and directional relationships that were found. The absence of variability amongst the control group's scores on the SST led to correlation coefficients that were not applicable in all of the three FSTs. This phenomena was not suprising as it was anticipated that all of the subjects with normal shoulders (control group) would rate 12/12 on the shoulder function rating score (SST).

D-2. Functional Shoulder Test - Visual Analogue Scale (pain)

Shoulder Rotation Test

In the SRT, correlation tests were calculated between the subjective rating of pain and each individual test for both groups. In the first test, "Speed 1", subjects with normal shoulders produced a statistically significant correlation value of -0.425. This meant that a high test result on the SRT (ie. high number of shoulder rotations), was matched with a low rating of pain experienced. This was the directional relationship that was expected to occur. Unfortunately, subjects with AASI, did not produce a strong correlation, in fact it was extremely low at -0.002.

Speed 2 generated low correlations in both study groups: -0.178 in the control group and -0.113 in the experimental group. They did however both show the directional relationship that was expected. Speed 3 was not much different, resulting in a -0.194 correlation amongst the controls and 0.044 for the experimental subjects. Although the correlation value is very low, the positive direction for the AASI subjects is puzzling. The 20 second test produced a significant correlation in the control group of -0.475, however a low,

reverse direction correlation of 0.246 in the experimental group was not what was anticipated.

The only significant correlations found between the SRT and the VAS for pain were in the control group at Speed 1 and 20 Seconds. The direction of these two correlations supports the theory that if a subjects' performance on the SRT is high, their feeling of pain must be low. Although this was demonstrated nicely amongst the normals in this study, the absence of this observation in the AASI subjects was not what was expected. Once again, strong statistical findings previously with respect to the FSTs, lead one to question the use of the VAS tool for pain for AASI patients. Pain perception is extremely variable amongst individuals and perhaps this phenomena is being evidenced in this study's results.

Light Board Test (LBT)

Two significant correlations were detected between the results of the LBT and the rating of pain. The most impressive one occurred between LBT-2 and the pain rating in the experimental group. This value generated was -0.573 which indicates that subjects' with lower scores on the LBT had higher ratings of pain during the test. The other significant correlation found was during LBT-3 amongst the control subjects. A value of 0.438 was calculated which indicates that as the number of lights touched increased, the amount of pain experienced also increased. This finding is in the reverse direction from what was expected, however it may be explained as representative of a normal, exertional relationship, in which a subject might experience some normal discomfort with considerable effort.

Overhead Throw Test (OTT)

The correlation between the OTT results and the subjects' rating of pain, were not found to be significant. A higher value (-0.219) was generated by the experimental group (control group = -0.167), and the negative description of the correlation was evidenced, unfortunately not to the degree that was anticipated.

No obvious explanation can be offered to interpret the correlation results generated between the FSTs and VAS (pain). Numerous research projects and strong clinical reporting have suggested that pain is a significant complaint amongst individuals with AASI, particularly if they are performing functions in an overhead, dynamic manner. Previous results from this study have demonstrated significant differences in the two study groups performance on these FSTs as well as highly significant differences in their ratings of pain during the testing. The reason why these two variables did not correlate significantly then is difficult to understand.

D-3. Functional Shoulder Test - Visual Analogue Scale (instability)

Shoulder Rotation Test (SRT)

There were no statistically significant correlations found between the two study groups' SRT results and their corresponding rating of instability. Similar to the FST-VAS (pain) results, a negative correlation was expected, matching a high score on the VAS-instability rating. The highest correlation that the control subjects' results produced was 0.262 and the direction of the relationship was positive. With the exception of the first test, Speed 1, all of the experimental group subjects produced negative results, meaning that as their SRT

score went down, their rating of instability went up. Unfortunately, none of these values were at a significant level.

Light Board Test (LBT)

One very significant correlation was detected between the LBT-2 and the experimental groups' rating of instability. In fact it was calculated to be -0.511 which is significant at a 0.001 level. This study's significance criteria was set at 0.01. Unfortunately the interpretation of this significant correlation is unclear, as it occurred during LBT-2, not LBT-3, which was the more difficult test that demonstrated the greatest difference between the two group means. The correlation found at this LBT was weak at -0.156. It would not seem logical that at a faster rate of joint motion and muscle activity, subjects with AASI would feel a greater sense of stability. Correlation values between the control group's LBT results and their rating of shoulder instability, were found to be not applicable because all of the subjects in this group rated their sense of instability at 0.0.

Overhead Throw Test (OTT)

There was a low, positive correlation (0.206) seen between the control subjects OTT results and their VAS-instability results. This positive relationship might be explained similarly to what occurred in the control group during LBT-3. As the subjects' effort level increased, while performing the overhead throw motion, their sense of GH joint instability also increased, albeit slightly. The experimental group demonstrated essentially no correlation between these two variables, producing a value of -0.003.

In summary, only one correlation was found to be significant in comparing the FST results and the VAS instability rating. Unfortunately, this correlation did not follow a logical pattern relative to the findings of the FST involved.

E. Clinical Significance

Present techniques for evaluating the individual with AASI are based primarily on subjective data gathering, through history taking and subjective rating scores, and objective clinical testing which includes range of motion measurements, strength testing and GH joint instability and impingement tests.

Measurements of function at the shoulder joint are limited to subjective rating scores which define shoulder function almost entirely upon the ability to perform basic, activities of daily life. Patients with AASI are often aggravated, not by these basic daily activities, but by tasks that involve overhead, often dynamic shoulder motions. The objective functional shoulder tests utilized in this experiment were designed in an effort to reproduce some of these overhead, dynamic shoulder motions and in turn provide the clinician with a measurement tool of an individual's ability to perform a functional task.

The FSTs presented in this study proved to be able to obtain objective information regarding the functional status of subjects with AASI. Two of the three FSTs utilized produced highly significant statistical differences in comparing the results of subjects with normal shoulders and subjects diagnosed with AASI. Subjects in the control group (normal shoulders) performed significantly better than subjects in the experimental group (AASI). These findings suggest that the tests were successful in discriminating between the two

subject populations that were examined and were effective in producing symptoms of pain and instability in the subjects with AASI.

The relationship between AASI and what has been termed "secondary impingement" has been discussed in previous chapters. A "relative" decrease in subacromial space causes the impingement, however, it occurs as a result of GH joint instability. Several authors have investigated this relationship between secondary impingement and instability and have agreed that in most instances, the two syndromes overlap and it is very difficult to distinguish between them (Hawkins and Kennedy, 1980; Jobe and Kvitne, 1989; Warner et al, 1990; Matsen et al, 1991; Allegrucci et al, 1994). It is important to note, in discussing this study's results, that the FSTs utilized did not distinguish atraumatic anterior shoulder instability from secondary impingement. Therefore, any conclusions made regarding the results of the instability subjects that were examined might also apply to individuals with secondary impingement. Further study into the sensitivity and specificity of these types of function tests is required.

The quantification of shoulder function has several clinical implications. It provides the clinician with information regarding the patient's ability to perform functional tasks and the amount of pain and sense of apprehension and/or instability that may be associated with these tasks. It may also help clinicians in evaluating patients' treatment programs by monitoring their progress through pre and post treatment measures. In an athlete or an individual involved in repetitive overhead work, these shoulder function tests, and the measures they generate, may provide the clinician with important information regarding that individual's ability to return to the sporting activity and/or to work in which they were previously involved. They may also be useful in assessing the effectiveness of different

rehabilitation programs used to treat AASI, or as a means of comparing the functional outcome of individuals following surgical procedures for anterior shoulder instability.

Although some of the equipment utilized in this particular study was cumbersome and not easily accessible to all clinicians, the principles upon which the function tests were designed are straightforward and the tests may be reproduced with very little effort. The Overhead Throw Test (OTT) was one of the two function tests that demonstrated a significant difference when comparing individuals with normal shoulders to those with atraumatic anterior shoulder instability. This test consisted of a softball attached to a standard tubing material, and required only a door frame to fixate one end of the tube, and an object that could act as a target for the subjects' aim. The simplicity of the equipment used as well as the easy set up makes the OTT ideal for a clinical setting.

CHAPTER SIX

SUMMARY AND CONCLUSIONS

A. Summary

The purpose of the present study was to utilize three objective functional shoulder tests (FSTs): the Shoulder Rotation Test (SRT), the Light Board Test (LBT) and the Overhead Throw Test (OTT), and compare the results generated from these tests on subjects with atraumatic anterior shoulder instability (AASI) and subjects with normal shoulders. The FST results obtained from both study groups were also compared to two subjective rating scores, one representing function (Simple Shoulder Test, [SST]) and one representing pain and sense of instability (Visual Analogue Scales, [VASs]) to determine if any correlation between the subjects' results existed.

Forty subjects participated in the study, twenty in the experimental group (AASI) and twenty in the control group (normals). All subjects underwent a clinical examination by the author as well as an orthopaedic surgeon to ensure all inclusion and exclusion criteria were met prior to participation in this study.

The purpose of the three FSTs, that were utilized in this study, was to determine and quantitatively measure the ability/inability of an individual to perform designated functional tasks. These functional tasks were designed to reproduce functional joint positions, muscle performance and neuromuscular patterns typically used at the glenohumeral (GH) joint.

Descriptive statistics and t-test analyses were calculated on: 1) subject demographic information, 2) the Simple Shoulder Test results, 3) the Visual Analogue Scale results, and 4) the three Functional Shoulder Tests, to determine if a difference occurred between subjects in the two study populations. A 0.01 level of significance was chosen to be conservative, and to minimize the risk of Type I errors occurring as a result of repeated t-tests being used. Pearson product moment correlation tests were used to calculate the correlations between the FSTs and the SST and the FSTs and the VASs.

All of the FSTs, with the exception of one of the individual LBTs, produced higher average scores in the control group. Two of the three FSTs demonstrated highly significant differences between the two groups of subjects. These were the SRT and the OTT. The LBT failed to produce a difference that was considered statistically significant, however it did demonstrate a directional trend towards significance with the experimental group generating lower performance scores as the test became more challenging. Only a small number of correlations were found to be significant between the variables examined.

B. Suggestions for Future Research

The directions and suggestions for future research, in the area of functional shoulder testing, are exciting and abundant. Several different areas of study are required in order to fully understand the challenges and issues that relate to this topic.

First of all, further investigation with the FSTs presented in this study would prove worthwhile. Even though very encouraging and significant results were discovered, questions arise regarding the specific protocols utilized with the FSTs themselves (ie. the

speed that the lights came on and off during the LBT), as well as with the subjective measurement tools that were chosen to represent pain and instability.

It would also be of interest to investigate different types of shoulder instabilities and impingement syndromes against a similar normal population to determine if the FSTs are able to discriminate between other groups of individuals. The most obvious population to examine would be individuals with primary and secondary impingement syndromes. It has been mentioned previously that the conditions AASI and secondary impingement, are very interrelated and as a result, it is difficult to distinguish between them in testing procedures. This was the case in the results generated from this study as well. Further investigation regarding the sensitivity and specificity of the FSTs to distinguish between different shoulder pathologies is required.

As mentioned previously, the FSTs could be utilized as a measurement tool prior to and at the completion of different treatment regimes to help determine the effectiveness of different interventions. An analysis of the FSTs' inter-tester and intra-tester reliability would be essential if these types of pre and post treatment studies were to be done.

The absence of a "gold standard" for measuring shoulder function makes any validity impossible for the time being, however, as more research is done in this area, these types of studies will become very important.

Other related areas of research include establishing a definition of shoulder function that better represents the needs of an atypical individual such as an athlete, the disabled and the

elderly. Once a definition is established, further study is needed to develop a means of measuring shoulder function both subjectively and objectively.

C. Conclusions

The results of this study support the theory that individuals with AASI have more difficulty performing certain functional tasks involving the shoulder, than individuals with normal shoulders. Epidemiological and etiological studies have shown us that these individuals are challenged by overhead, dynamic activities which often require fast joint reaction times and considerable neuromuscular coordination. The subjects utilized in this experiment demonstrated this phenomena in two of the three FSTs, failing to complete as many shoulder rotation motions and overhead throw motions as the subjects with normal shoulders.

Results generated from the SST and the VASs, although significantly different when comparing the individual groups, failed to correlate consistently with the results of the FSTs.

Based on the findings of this study, the following recommendations are made:

- 1) Although both the SRT and the OTT were shown to be very effective in measuring the functional ability/inability of individuals with AASI, the OTT is the test that is recommended. The equipment necessary is simple, inexpensive and readily available in most clinical settings and it requires only a minimal amount of space to perform the test.

2) A subjective rating scale that measures an individual's sense of instability, such as the visual analogue scale, is recommended in conjunction with the OTT. Measuring pain, although important, is difficult because it is dependent upon several factors which may have little to do with the injury itself. It also does not distinguish well between different shoulder pathologies such as instability, impingement and rotator cuff injuries. The sensation of instability, however, is predominant in patients with AASI, especially in overhead throwing positions.

3) The use of a subjective functional rating score, unless modified to specifically address the complaints of patients with AASI is not recommended as a valuable assessment tool.

This study introduced three objective functional shoulder tests for consideration in the overall evaluation of the individual with AASI. The results are very encouraging at this early stage, especially in the absence of a "gold standard" measurement tool for shoulder function. Continued research on the use of objective functional tests at the shoulder joint is certainly required. Following this, the integration of these types of functional testing techniques into the traditional method of evaluating the shoulder, may prove to be very beneficial for the clinician faced with the challenges of diagnosing and managing this sometimes very difficult condition.

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APPENDIX A:
CLINICAL GLENOHUMERAL JOINT INSTABILITY TESTS



The anterior apprehension test is performed with the subject in sitting with his/her shoulder abducted to 90 degrees. The examiner applies an anterior pressure on the proximal humerus while externally rotating and horizontally extending the shoulder. The test is considered positive if the subject demonstrates apprehension, tenses the muscles surrounding the shoulder and/or relates a feeling of or an actual subluxation.



The relocation test (Fowler's sign) confirms the anterior instability suspected with the anterior apprehension test and is performed with the subject supine. The shoulder is abducted, externally rotated and horizontally extended to the point at which the subject demonstrates the positive symptoms of the apprehension test. The examiner then applies a posterior pressure over the proximal humerus and the humeral head and if this allows for an increased external rotation and/or abduction of the shoulder or a reduction of pain, the test is considered positive.



The load and shift test is performed with the subject in sitting. The examiner stabilizes the subject's scapula with one hand, grasps the humeral head with the other hand, and attempts to glide the humeral head anteriorly or posteriorly. An anterior glide is considered positive when a void is produced under the posterior acromion and a posterior glide is considered positive when more than 50 percent of the humeral head can be translated off of the glenoid posteriorly.

**APPENDIX B:
VISUAL ANALOGUE SCALES**

Visual Analogue Scale For Test One:

I. Pain

Indicate the amount of pain you experienced while performing the functional shoulder test by marking a point on the line.

no pain ————— the worst pain imaginable

II. Instability

Indicate the degree to which your shoulder felt unstable while performing the functional shoulder test by marking a point on the line.

no sense of instability ————— the most severe sense of
instability imaginable

APPENDIX C: SUBJECT RECRUITMENT LETTER

Dear :

I am presently involved in a research project as part of my Master's degree requirement. The project's purpose is to utilize three objective functional shoulder tests (FSTs) and compare the results from these tests on subjects with atraumatic anterior shoulder instability (AASI) and subjects with normal shoulders to determine if a significant difference exists between the two study groups. These results will then be compared with results attained from a subjective function rating score and two visual analogue scales measuring pain and instability.

The inclusion and exclusion criteria for the experimental group (AASI) are as follows:

- Inclusion:
- men and women between the ages of 16 and 35
 - reported subjective history of recurrent shoulder pain and/or instability
 - a positive anterior apprehension/relocation test
 - a positive load and shift test (in an anterior direction)
- Exclusion:
- surgical procedure of affected shoulder and/or shoulder girdle
 - any neurological signs and/or symptoms originating from the C-spine
 - history of rotator cuff tear
 - history of glenohumeral joint dislocation
 - history of any fracture to the shoulder and/or shoulder girdle
 - history of sprain and/or separation of acromioclavicular joint
 - history of sprain and/or separation of sternoclavicular joint
 - symptomatic** multidirectional instability (defined as pain and/or in an inferior and/or posterior direction)
 - inadequate active range of motion (ROM) to perform the functional tests
 - grade II (moderate) or grade III (severe) impingement signs
- instability

The testing procedures will consist of a clinical examination, filling out a shoulder function rating score and three functional shoulder tests designed to reproduce functional movement patterns of the shoulder region.

If you have any patients that you feel might be appropriate or participation in this study, could you please have them contact me at the GSSMC. If you have any questions or concerns regarding the subjects and/or the study itself, please do not hesitate to contact me.

Thank you.

APPENDIX D: SUBJECT CONSENT FORM

Functional Shoulder Testing for Atraumatic Anterior Shoulder Instability

Purpose of Research

Atraumatic Anterior Shoulder Instability (AASI) is a clinical condition seen commonly in sports and occupations that involve overhead positions and movements. Typical testing procedures have included clinical examinations and stability tests performed in static, unspecific settings. A large majority of activities that involve the shoulder region require a component of speed, endurance, coordination and positions that are overhead and often awkward.

The objective of this study is to use three functional shoulder tests which reflect activities of daily life and sports to determine which test most accurately detects this type of instability.

During the shoulder tests, you will be asked to perform: 1) a repetitive shoulder rotation motion at different speeds, 2) an arm to eye coordination test involving a light board, and 3) a repetitive overhand throwing motion. Prior to doing the tests, you will be allowed a trial, warm-up period on all of the tests. At the completion of each of these tests you will be asked to rate the amount of pain and instability you experienced during the test.

Prior to performing the shoulder tests, your shoulder joint will be assessed by an orthopaedic surgeon and you will be asked to fill out a twelve question questionnaire regarding the functional capabilities of your shoulder. Following the examination by the orthopaedic surgeon you may be excluded from participation in the study based on the inclusion/exclusion criteria that have been established for all potential subjects.

Because the three tests you will be doing are active and reflect positions and motions that your shoulder would do during normal work and sporting activities, there is a risk of causing normal muscle soreness, discomfort and glenohumeral joint instability. The risks are minimal but it is important that you are aware that they may occur. If following the testing you have any of these symptoms persisting more than 2-3 days, you are advised to contact Judy Chepeha at 492-4752.

If at any time during the testing you do not feel capable or confident to perform the test, you are free to withdraw from the study without prejudice or coercion. All records and data collected from this study will be kept strictly confidential and you will be referred to by subject number only in any publication or material that might follow. If you have any questions, they can be answered now or at any time in the future by calling Judy Chepeha at 492-4752.

Subject Name

Signature/Date

Investigator Name

Signature/Date

**APPENDIX E:
CRITICAL CORRELATION VALUE (r-crit) CALCULATION**

Degrees of Freedom = 38 (based on a total of 40 subjects - 2)

Level of Significance:	r-crit:
0.05	0.31
*0.01	*0.40
0.001	0.50

Referenced from Meyers, Rossen, 1974.

*For this particular study, a 0.01 level of significance was utilized, therefore a correlation value of 0.40, or greater, was required for the correlation between the variables being measured, to be considered significant.

APPENDIX F:
INTER-RELIABILITY TEST RESULTS OF CLINICAL EXAMINATION

Stability Tests:	ICC's (R)
anterior apprehension/relocation test	1.000
load and shift test	1.000
symptomatic sulcus sign	1.000
Impingement Tests:	
abduction/internal rotation	1.000
Hawkin's test	1.000
ROM (painful arc)	1.000
ROM (reversed SHR)	1.000
ROM (restricted abduction)	1.000

The clinical examination was performed to ensure that all subjects successfully met the inclusion/exclusion criteria established for participation in this study. Both the investigator and the orthopaedic surgeon tested all potential subjects and if any discrepancy was discovered, that particular subject was disqualified from participation. None of the subjects examined were disqualified for this reason.

APPENDIX G: SAMPLE SIZE CALCULATIONS

Sample size was calculated as a function of the effect size (d), the significance level (α) and power.

Significance level = 0.01

Effect Size = 0.65

Power = 70

The level of significance (0.01) was chosen to be conservative and minimize the risk of Type I errors occurring from utilizing repeated t-tests in the statistical analysis. An effect size of 0.65 was selected as it was felt that the probability of the results from this study yielding significant results would be at least 65%.

According to the power table (Meyers and Grossen, 1974), the above mentioned values produce a sample size of 40.

**APPENDIX H:
SUBJECT DEMOGRAPHIC DATA COLLECTION**

Subject Demographics

Subject No. _____ Name _____

Age _____

Sex _____

Weight (in kg) _____

Height (in cm) _____

Activity Level _____

I. Competitive - participation in sports activity 6-7 times per week and/or regular participation in organized competition or activity of a similar intensity.

II. Recreational - participation in sports activity 3-5 times per week or 2 times a week for more than 2 hours per session.

III. Weekend - participation in sports activity 2 or less times per week with each session lasting approximately 1 hour per session.

IV. Sedentary - no participation in sports or activity of a similar intensity.

Occupation _____

Hand Dominance _____

Shoulder Tested _____

Generalized Ligamentous Laxity Profile:

1) elbow hyperextension	yes	no
2) knee hyperextension	yes	no
3) thumb to forearm/wrist	yes	no
4) 5th MCP joint hyperextension	yes	no

APPENDIX I: CLINICAL EXAMINATION

SUBJECT NO. _____

CLINICAL TESTS

Stability tests:

anterior apprehension/relocation test	+	--
load and shift test	+	--
symptomatic sulcus sign	+	--

Impingement tests:

abduction/internal rotation	+	--
Hawkin's test	+	--
ROM (painful arc)	+	--
ROM (reversed SHR)	+	--
ROM (restricted abduction)	+	--

ROM required to perform functional tests:

90 degrees abduction	+	--
90 degrees of scaption	+	--
90 degrees ER (in 90 deg. abduction)	+	--
45 degrees IR (in 90 deg. abduction)	+	--